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An Analysis of Three of the Components Contributing to Performance in Ice Hockey for Boys Aged 13 to 16 Years

by

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The undersigned certify that they read, and recommend to the faculty of Graduate Studies and Research, for acceptance, a thesis entitled, "An Analysis of Three of the Components Contributing to Performance in Ice Hockey for Boys Aged 13 to 16 Years", summitted by André Dorion in partial fulfilment of the requirements for the degree of Doctor in Philosophy.

ABSTRACT

The purpose of this study was to analyze three of the components contributing to performance in ice hockey. It was also part of this study to investigate the structural validity of on-ice skating skill tests and to compare two sub-groups of subjects (bantam and midget) on the factors contributing to ice hockey performance.

In order to investigate the sport of ice hockey, factor analysis (principal components) was used. The four factors retained by the principal components procedure confirmed the theoretical factors and subdivised the anthropometrical factor into anthropometrical and skinfold factors. The skating skill tests were combined as one factor (skating skill tests factor).

The validity of the skating tests was defined as the relationship between the skating tests and the skating skill tests factor ("structural validity" as defined by Leovinger, 1957). The relationship was expressed by the loadings of the tests under the factor. These relationship suggested that all the skill tests used were of good (loading greater than 0.50) validity (in regard to the structure).

Finally, the comparison of the two sub-groups on the factors contributing to overall performance showed significant differences between the sub-groups for the anthropometrical factor. No significant differences were found for the skinfold, and skating skill tests factors.

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ABD	Skinfold - abdomen (mm).
AER	Aerobic capacity on ice - 8 minutes (sec).
AGE	Age (months).
AOI	Agility on ice - backward (sec).
AWP	Agility on ice - without a puck (sec).
BA90	Speed skating - backward 90 feet (sec).
BA120	Speed skating - backward 120 feet (sec).
BIAC	Body width - bi-acromial (mm).
BITR	Body width - bi-trochanter (mm).
CAHA	Canadian Amateur Hockey Association.
CAR	Body circumference - upper-arm (mm).
CFA	Body circumference - forearm (mm).
CHE	Skinfold - chest (mm).
CLE	Body circumference - leg (mm).
CLL	Body circumference - lower leg (mm).
CWR	Body circumference - wrist (mm).
F90	Speed skating - forward 90 feet (sec).
F120	Speed skating - forward 120 feet (sec).
HAN	Agility on ice - Hansen's procedure (sec).
HEI	Height (cm).
JAR	Jump and reach test (in).
LAR	Body length - upper-arm (mm).
LFA	Body length - forearm (mm).
LLE	Body length - leg (mm).
LLL	Body length - lower leg (mm).
MAR	Agility on ice - Marcotte's procedure (sec).
MID	Skinfold - mid-axila (mm).
PBF	Percentage of body fat (%).
PWC	Physical work capacity 170 (kpm/min).
PWCW	PWC_{170}/weight (kpm/kg.min.).
SIT	Sit-ups (#).
SUB	Skinfold - sub-scapular (mm).
SUP	Skinfold - supra-iliac (mm).
TRI	Skinfold - triceps (mm).
VO2	Maximal oxygen uptake (predicted) - (l/min.).
VO2W	VO_2/weight (ml/kg.min.).
WEI	Weight (kg).

CHAPTER I

THE PROBLEM

A. Introduction

Many factors supposedly contribute towards the "excellence" of the player in ice hockey. In the past, "excellence" in ice hockey players has been determined by the measurement of on-ice skills as well as physiological measures such as aerobic and anaerobic power and endurance. Most of the research done in ice hockey has analysed one of the previously mentioned components. A number of researchers developed tests to measure on-ice skills performance: Brown, 1935; Sabasteanski, 1949; Dewitt, 1953; Percival, 1956; Tower, 1959; Devincenzo, 1960; Doroschuck and Marcotte, 1966; Haché, 1967; Merrifield and Walford, 1969; Hansen et al., 1970; Cantelli, 1970; Fédération Suédoise de Hockey, 1971; Merrifield and Walford, 1971; Sicilliano, 1971; Hockey Canada, 1972; Enos, 1973; Jobin, 1975; Dulac et al., 1976; Larivière et al., 1976; 1976b; Graham, 1977; Hermiston et al., 1979 and Macnab, 1979.

Thiffault and Larivière (1970) found 30 studies in North America analysing technical skills divided into six categories: skating, puck handling, passing, shooting, body checking, and other skills.

The cardiorespiratory characteristics of ice hockey players were analysed in a number of other studies: Montpetit et al., 1971; Seliger et

al., 1972; Bouchard et al., 1974; Green and Houston, 1975; Cunningham et al., 1976; Deshaies et al., 1976; Dulac et al., 1976; Green et al., 1976; Houston and Green, 1976; Larivière et al., 1976; Bonen and Bobineau, 1977; Paterson et al., 1977; Hockey and Howes, 1978; Hutchinson et al., 1979; and Macnab, 1979. These authors studied the maximal oxygen uptake of ice hockey players in regard to the performance aspect or in predicting the maximal oxygen uptake from on-ice tests. Cunningham et al. (1976), Larivière et al. (1976b) and Shkhvatsabaya (1977) studied the physical work capacity of ice hockey players.

Anthropometrical studies of ice hockey players were reported by Bouchard et al. (1974) and Pirie (1974).

Until now, however, none of the previous researchers has attempted to link the three assumed components (skating skill, physiological and anthropometrical) to investigate if a more complex structure of a player could be developed.

An attempt was made in this study to demonstrate that the factors involved in ice hockey are best determined by a more complex structure consisting of interactions between the physiological, anthropometrical and skating skill components of performance.

It is important to mention that the present research sought factors for a typical competitive ice hockey player and not to predict the necessary components for ice hockey performance.

B. Statement of the problem.

The purpose of this study was to investigate the interrelationship among three major components of ice hockey performance: skating skill, physiological and anthropometrical measures of players 13 to 16 years of age. Such an investigation was done to create factors contributing to ice hockey performance.

In addition, this study was designed to:

1) investigate the structural validity of on-ice skating skill tests, and to

2) compare two sub-groups of subjects (13-14 years players: "bantam", and 15-16 years players: "midget") on the factor contributing to ice hockey performance.

C. Sample.

The sample consisted of 187 ice hockey players aged 13 to 16 years, playing in the Chicoutimi, Jonquière, Arvida, Kēnogami, Alma and Lac-St-Jean areas. These players were divided into two sub-groups:

1) Sub-groups I was composed of 88 players, 13-14 years of age (defined as "bantam" level by the C.A.H.A.).

2) Sub-group II was composed of 99 players, 15-16 years of age (defined as "midget" level).

It is important to mention that of the 187 players evaluated 21 were goaltenders (10 for sub-group I, and 11 for sub-group II), and 34 players were not able to complete all the tests (8 in sub-group I and 26 in sub-group II). In addition, for the factor analysis procedure and the comparison of the two sub-groups, the goaltenders were omitted. The goaltender's results for the on-ice tests were obtained by testing the goaltenders without their equipment (in gym suit).

All the players competed in the Saguenay-Lac-St-Jean region at the "AA" level. The "AA" level is the highest calibre of ice hockey in that region.

D. Significance of the study.

As previously indicated, very little research has been conducted to investigate the factors contribution to ice hockey performance utilizing all three components, ie. skating skill, physiological, and anthropometrical measures.

Results of this study could help the Canadian Amateur Hockey Association (C.A.H.A.) in the evaluation of its program and would contribute to the understanding of the make-up of an ice hockey player.

Second, the factors would certainly assist the coaches in the selection of ice hockey players through a better understanding of the different components and the interaction between them.

Finally, the results could help to validate the different tests used in this study which measured skating skill. Consequently, practionners would have greater confidence regarding the use of these tests and measures.

CHAPTER II

REVIEW OF THE LITERATURE

There are areas in physical education which pertain directly to this study: skill components of a specific sport, exercise physiology (in general and applied to a sport), and a statistical procedure called factor analysis. The review of the literature will focus on the skills, exercise physiology and anthropometry as they are applied to the sport of ice hockey. The statistical method of factor analysis has previously been employed to solve physiological and skill components problems. But no literature was found reporting the use of factor analysis in ice hockey research. Thus the review of the literature on factor analysis is limited to selected studies in order to give a broad overview of the application of factor analysis in physical education.

A. Ice hockey.

This section contains a review of the research done in ice hockey specifically focusing on three components: the cardiorespiratory fitness components of the player, the anthropometrical components, and the tests used in measuring the skills of the players.

Prior to 1972, Canada's superiority in the sport of ice hockey was not considered to be in jeopardy. To the dismay of many, the first real confrontation with the Soviet Union shook North American's confidence in

the system for developing ice hockey players. Some people reacted to the situation by studying the different characteristics of the players.

Marcotte (1974) attempted to establish guide lines for research in ice hockey. One of his first conclusions was that there was a need to establish a research centre for ice hockey. This centre would help to organize ice hockey research and would store all pertinent information about the sport. He also underlined the complexity of ice hockey:

> "Le hockey se jouant à de très grande vitesse et permettant le contact, exigeant des gestes inusités dans la vie courante, tel le coup de patin et les lancers, est un apprentissage lent et laborieux". (Marcotte, 1974).

and one of his conclusions concerning future research in ice hockey was:

> "Nous devrons créer un esprit d'équipe autour des meilleurs éléments de la province ... Elle devra, par la suite, trouver les outils nécessaires à la réalisation des buts fixés." (Marcotte, 1974).

To date, although Marcotte's recommandations have not been acted upon, the components of ice hockey are better understood. Hansen and Jetté (1976) wrote about the physical (anthropometrical and physiological) and skills components. Thiffault and Larivière (1976) reported more than 30 studies dividing the skills into six categories: skating, passing, puck handling, shooting, body checking, and others, and they recognized 115 technical movements specific to ice hockey. Their findings supported Marcotte's (1974) statement regarding the complexity of ice hockey. The skills components are just of example. Hansen and Jetté (1976) discussed the physical components and didided it into power endurance, strength, speed,

recovery, agility, and flexibility. An additional component identified by Pirie (1974) is that of the somatotype of an ice hockey player.

1. Physiological components of ice hockey players.

Paterson (1979) defined the aerobic components as the most prominent physiological component of ice hockey, in relation with the anaerobic component:

> "Clearly, though, ice hockey has a large anaerobic component, the intermittent exercise nature involves maximal cardiorespiratory effort." (Paterson, 1979).

This statement was supported by Seliger et al. (1972):

> "Ice hockey proves to be an activity with mostly sub-maximal metabolic rate, where (sic) appears a great part of anaerobic metabolism simultaneously with high requirements for the aerobic metabolism". (Seliger et al., 1972).

Such statements can be found in a large number of studies (Houston and Green, 1976; Green et al., 1976; Shkhvatsabaya, 1977 and Hutchinson et al., 1979). The cardiorespiratory factor, the aerobic capacity, the oxygen uptake, and the physical work capacity are all well documented aspects of ice hockey performance as shown in table 1.

All of these studies conducted in the past decade attempt to measure the cardiorespiratory characteristics of ice hockey players. The variation in mean oxygen uptakes range from 46.6 ml./kg.min. (Deshaies et al., 1976) to 58.8 ml./kg.min. (Paterson et al., 1977), but it is considered "low" when compared to the oxygen uptake of athletes of the same age group

TABLE 1

Means and standard deviations of VO_2 max. and PWC_{170} of ice hockey players from various studies.

Studies	VO_2 (ml./kg.min.)	PWC_{170} (kpm./kg.min.)	N	Age means (years)
Bouchard et al.-1974	54.1(5.9)		12	25.3
	58.4(5.2)		24	18.2
Houston and Green-1976	56.3(5.4)		19	17.9
	54.6(4.5)		7	21.3
	55.6(4.1)		9	17.8
	53.6(1.3)		3	20.3
Deshaies et al.-1976	46.6(6.4)		116	17.9
Hockey and Howes-1978	53.3(5.0)		15	13.7
Green et al.-1976	53.2(?)		8	21.0
Hutchinson et al.-1979	57.9(5.7)		9	18.5
Cunningham et al.-1976	56.6(7.7)	14.55(2.5)	15	10.6
Bonen and Bobinau-1977	54.9(4.8)		52	20.7
	53.7(5.3)		24	21.5
Paterson et al.-1977	58.8(2.4)		14	10.7
	56.6(1.3)		14	10.1
Seliger et al.-1972	54.6(5.3)		13	24.4
Shkhvatsabaya-1977		15.00(2.5)	26	11.0
		15.60(0.6)	27	12.0
Montpetit et al.-1971	55.5(5.2)		15	20.4
Green and Houston-1975	56.4(4.3)		18	16.20
	57.1(4.0)		18	16.20
Macnab-1979	56.0(?)		15	11.0
Larivière et al.-1976	55.4(4.8)		13	14.5

TABLE 1 (Continued)

Means and standard deviations of VO_2 max. and PWC_{170} of ice hockey players from various studies.

Studies	VO_2 (ml./kg.min.)	PWC_{170} (kpm./kg.min.)	N	Age means (years)
Dulac et al.-1976	56.5(6.1)		26	12.3
	55.2(6.7)		21	14.4
	55.3(4.1)		20	16.6
	58.4(5.2)		5	17.8
Larivière et al.-1976	15.70(3.7)		15	9.10
	17.10(3.7)		19	11.12
	15.30(2.7)		16	13.14
	18.10(4.0)		18	15.16

in other sports (Houston and Green, 1975). Other aspects such as the prediction of the maximal oxygen uptake from the distance skated in a set period of time were investigated. Hockey and Howes (1978) reported a coefficient of correlation of r:0.60 between the distence skated in 12 minutes and the maximal oxygen uptake of the players. That relation was based on 15 subjects (average age of 13.7 years) who were not very homogenous on the oxygen uptake or the distance skated. The small number of subjects is an important factor in the interpretation of the coefficient.

Rey et al. (1977), Green et al. (1978) and Paterson (1979) estimated the average on-ice intensity at 70 to 80% of the maximal oxygen uptake (maximum aerobic power) for players who played 45 minutes or more per game (the average age ranging from 10.5 to 21.0 years).

In summary, it can be said that some physioligical characteristics of ice hockey players are becoming well documented, specifically the cardiorespiratory aspect. Much research has yet to be done on other physiological aspects such as muscle function, anaerobic threshold and biochemistry.

2. Anthropometrical components of ice hockey players.

Only two major anthropometrical studies have been conducted in North America which used ice hockey players. Bouchard et al. (1974) obtained the anthropometrical measures of 36 players (12 professionals and 24 juniors: 17 to 19 years of age) on four body widths, six body circumferences, six

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skinfold measures, somatotype, and percentage of body fat. These results were not discussed. Pirie (1974) studied the somatotype of 61 ice hockey players (10 years of age). In doing so she took four skinfold measures, two bone diameters, and two muscle girth measures. While both studies were descriptive, only Pirie's (1974) study discussed the results of the somatotype of the player. She concluded that hockey playing ability is not related to those aspects of physical growth assessed by a somatotype rating. Numerous other studies have examined only the subjects' body fat aspect of anthropometry (Montpetit et al., 1971; Green and Houston, 1975; Dulac et al., 1976; Green et al., 1976; and Larivière et al., 1976).

3. Tests measuring on-ice skills.

The different components of on-ice skills are becoming well documented. Thiffault and Larivière (1976) developed a taxonomy, including 105 basic technical principles. These principles were placed under six categories: skating, passing, shooting, body checking, stickhandling, and others. If we compared these categories with research done using skills tests (Table 2) it become evident that the skating and stickhandling categories are the ones most often used (3:1). Going back to the taxonomy of Thiffault and Larivière (1976) it can be said that the skating speed (forward and backward), agility tests (including turns, stop and go, and jumps) were the principles most often evaluated in the skating category.

Within the stickhandling category, the tests defined as "stickhandling and puck control", and "agility" (Table 2), were the ones

TABLE 2

Studies involving on-ice tests.

Studies	Tests[1]
Brown[2] - 1935	FS - ST - SH
Sabasteanski[2] - 1949	AG
Dewitt[2] - 1953	FS - ST - SH
Percival[2] - 1956	FS - ST - AG - SH
Tower[2] - 1959	FS
Devincenzo[2] - 1960	FS - ST - AG - SH
Doroschuck and Marcotte - 1966	AG
Haché - 1967	FS - BS - ST - AG
Merrifield and Walford - 1969	FS - BS - ST - AG - SH - PA
Hansen et al. - 1970	FS - BS - ST - AG - SH - PA
Cantelli - 1970	FS - BS - ST - AG - SH - END
Merrifield and Walford - 1971	FS - BS - ST - AG
Siciliano - 1971	FS - BS - ST - AG
Féd. Suédoise de hockey[2] - 1971	FS - BS - ST - AG
Hockey Canada - 1972	FS - BS - AG
Enos[2] - 1973	FS - ST - AG - SH - PA
Jobin - 1975	FS - BS - SH - AG
Larivière et al. - 1976	END - RES
Larivière et al. - 1976b	END
Dulac et al. - 1976	END - RES
Graham - 1977	FS - BS - ST - SH
Hermiston et al. - 1979	AG
Macnab - 1979	FS - BS - ST - SH

[1]- FS: Foward Skating
- BS: Backward Skating
- ST: Stickhandling
- AG: Agility
- RES: Resistance
- END: Endurance
- SH: Shooting
- PA: Passing

[2]- From Thiffault and Larivière (1976).

developed by Merrifield and Walford (1969), Doroschuck and Marcotte (1966), Hockey Canada (1972), and Hansen et al. (1970). Il should be noted that the endurance and resistance tests developed by Larivière et al. (1976b) are classified under the category of skating.

a) Speed tests.

Merrifield and Walford (1969) were one of the first groups to introduce a 120 foot distance for a speed skating test performed both forward and backward. They tested 15 male college students after one week of practice, on two occasions, one week apart. The test-retest reliability on the tests (Table 3) showed agreement between the two sessions (forward; r:0.74, backward; r:0.80) and the validity showed coefficients indicating agreement between the results of the tests and the rating of experts (forward; r:0.69 to 0.77, backward; r:0.64 ot 0.70). Hansen et al. (1970) used the 120 foot test, forward and backward, as well as the 60 and 90 foot distance for testing 200 subjects aged 8 to 18 years. Their coefficients of reliability (test-retest), presented in Table 3, varied from r:0.57 (forward 60 foot) to r:0.88 (backward 120 foot). Merrifield and Walford (1971) undertook a second study on ice hockey skills and in doing so they repeated the 120 speed test on 94 subjects, 8 to 11 years of age. Once again they reported high reliability - test-retest- (forward; r:0.81, backward; r:0.92) and validity coefficients - ranking of expert versus performance- (forward; r:0.83, backward; r:0.70). It should be noted that for on-ice tests, a coefficient of reliability is considered high when

TABLE 3

Reliability and validity of on-ice skating tests.

Tests	Reliability (test-retest)	Validity (expert vs. performance)
Forward speed		.69 , .69 , .77 , .64[3] .83[4]
60 feet	.57[1]	
90 feet	.64[1], .85[2], .81[3]	
120 feet	.76 , .81[3]; .74[4]	
Backward speed		.64 , .70 , .64 , .64[3] .79[4]
60 feet	.80[1]	
90 feet	.85[1], .93[2]	
120 feet	.88[1], .92[2], .80[4]	
Agility		.46 , .83 , .73 , .75[3] .75[4], .83[6]
Hansen's	.48[1]	
Marcotte's	.90[2], .93[6]	
Merrifield's	.88[3], .94[4]	
Stickhandling		.77 , .70 , .87 , .83[3] .96[4]
Hansen's	.61[1], .94[2]	
Marcotte's	.80[1]	
Merrifield's	.97[3], .93[4]	
Endurance 8 minutes	.75[2], .79[7]	

1- Hansen et al. (1970), N:188; 8 to 18 years.
2- Larivière and Godbout (1976), N: 26; 12 to 16 years.
3- Merrifield and Walford (1971), N:15; collegial level.
4- Merrifield and Walford (1969), N:94; 8 to 11 years.
5- Larivière (1974).
6- Doroschuck and Marcotte (1966), N:27; 18 to 25 years.
7- Larivière et al. (1976b), N:13; 14.5 years.

its value is more than 0.80, and a validity coefficient is high when its value is more than 0.50. Finally, Larivière and Godbout (1976) used the 90 speed test (forward and backward) as a criterion test for speed. They also calculated the test-retest reliability in testing 26 subjects of 12 to 16 years of age (forward; r:0.85, backward; r:0.93).

b) Agility tests.

Merrifield and Walford (1969, 1971) presented an agility test (N:94, 15; 8 to 11 years) that seems to be very similar to the one developed by Doroschuck and Marcotte (1966). This test had high test-retest reliability (r:0.88 and r:o.93) and high validity coefficient, the ranking of experts versus the test's performance (from r:0.46 to r:0.83; N:94, 8 to 11 years of age). The Doroschuck-Marcotte test was an adaptation of the Illinois Agility Run test and was validated on 27 subjects aged 18 to 25 years. The validation was done by seeking the relationship between test performance (in seconds) and subjective grading and ranking of the subjects on hockey ability by their instructor. The validity can be considered high (r:0.83). The only questions about the procedures followed are:

1) The number of subjects (27); and,
2) The observers (no comments were made on the number of instructors and on the inter-observer reliability).

Doroschuck and Marcotte (1966) reported also a test-retest reliability coefficient of r:0.93. Hansen et al. (1970) developed an agility test and evaluated 188 subjects aged 8 to 18 years. They reported a test-retest

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[illegible]

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[illegible]

[illegible]

reliability coefficient of r:0.48 which is the lowest coefficient found for an agility test. The authors did not discuss the reliability coefficient previously stated. No other studies were found which attempted to validate and to determine the reliability of the skating skills tests.

c) Stickhandling and puck control tests.

It may appear odd, but the stickhandling component of hockey skills has been analysed as much as the speed component (14 and 17 studies). Merrifield and Walford (1969, 1971) developed and used a stickhandling course. They conducted a reliability and validity study on young hockey players (N:94) and 15 college hockey players, reported in table 3. The coefficients of test-retest reliability are higher than the ones for the agility test (r:0.97 and r:0.93) and the validity coefficients (ranking of experts versus test's performance) range from r:0.70 to r:0.90, and are more than acceptable when compared with others. It seems that the stick-handling test is a more reliable and valid test than the agility test. A possible reason is the discrimatory power of the agility test when compared with the stickhandling test. Hansen et al. (1970) used the Doroschuck-Marcotte agility test in order to measure stickhandling. They reported a test-retest reliability coefficient of r:0.80, the study was conducted on university students (N:27; 18 to 25 years) participating in an ice hockey class. Finally, Hansen et al. (1970) developed their own puck control test. And Larivière and Godbout (1976) evaluated 986 young (6 to 16 years) hockey players and created norms using the Hansen et al. procedure

for a puck control test. Both studies reported test-retest reliability coefficients for the Hansen et al.'s test: r:0.61 (Hansen et al., 1970) and r:0.94 (Larivière and Godbout, 1976). The low coefficient can be explained by the fact that the Hansen et al. study analysed a more homogenous group of 188 players (8 to 18 years) than the Larivière and Godbout study; 986 players (6 to 16 years).

d) Endurance tests.

Another component of skating skills is the endurance factor. Few studies have reported results on endurance tests in skating. Larivière et al. (1976b) evaluated 13 players (average age: 14.5 years) on three skating endurance tests (eight minutes of continuous skating, five minutes of continuous skating, and five minutes of "stop and go"). The eight and five minutes continuous tests were highly correlated with the VO_2max. (l/min), r:0.70 and r:0.85 respectively, but only the five nimutes continuous skating test had a moderate correlation of r:0:58 with the VO_2max. when expressed per kg of body weight. Larivière and Godbout (1976) reported a test-retest reliability coefficient for the eight minutes test of r:0.75 (N;26, 12 to 16 years) and Larivière et al. (1976b) reported a validity (on-ice versus in-lab performance)coefficient of r:0.79 (N:13, average age:14.5 years).

Dulac et al. (1976) used two of the previously mentioned tests: the five minutes "stop and go" and the eight minutes of continuous skating. The eight minutes test correlated more with VO_2max. (l/min) than the five minu-

tes test (r:0.79 and r:0.70 respectively), however, the relationship with the $VO_2max.$ dropped significantly when $VO_2max.$ was corrected per kg of body weight. In this situation the coefficients of correlation were r:0.30 and r:0.32, respectively. The study evaluated 72 players between the ages of 8 to 18 years. Dulac et al. (1976) analyzed the data in order to predict the distance skated in the five and eight minutes tests using a regression equation on 15 variables. The multiple R's were 0.75 and 0.86, respectively. The value of such analyses is open to question. There is no reason to predit the distance skated in eight minutes from work loads (watts/min.), arm hang (sec), and percentage of body fat (%). The prediction of $VO_2max.$ from the distance skated in eight minutes would seem to be more valuable.

Finally, a study by Larivière et al. (1976) used the five minutes "stop and go" test. In addition, a set of laboratory variables (PWC_{170}, muscular strength, and body fat percentage) were measured, and the coaches' ratings were collected. The sample for the study was composed of 1066 boys on the five minutes skating test, and of 68 boys on the laboratory tests. The relationship between the coaches' ratings and the five minutes skating test displayed a large variation (r:0.31 to r:0.91). However, the authors did not discuss the source of the variation. The lack of relationship between the laboratory measures and the distance skated in five minutes was explained by the homogeneity of the groupe in terms of skating ability (the coefficient of variation for the skated distance ranged from 13.7% to 8.0%).

[illegible]

4. Profile of the ice hockey players.

Bouchard et al. (1974) conducted one of the most exhaustive studies on the physical and anthropometrical characteristics of ice hockey players. They studied two groups of players: Junior (N:24, average age: 18.2 years) and Professional (N:12, average age: 25.3 years). They measures ten categories of variables:

a) weight, height, four body diameters,

b) six skinfold measures,

c) six body circumferences,

d) three types of somatotype,

e) five measures of tissue composition,

f) two reaction-time measures,

g) six muscular strength tests,

h) five pulmonary measures,

i) ten measures extracted from submaximal tests and,

j) eleven measures extracted from maximal tests.

The players were also grouped by position and statistical comparisons were made by position as well as by level of competition. Few of the large number of variables showed a significant difference (at the 95% of probability) between the levels of competition (10 out of 60 variables), and none of the differentiating variables was discussed. A relationship analysis was made between the performance of the players (ratio of number of goals and assists per game) and the ten categories of variables. The

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[illegible]

relationship analysis was done at two levels:

1) simple correlation between the performance variable and each of the different variables included in the category, and
2) multiple regression between the performance variable and the category of variables.

The simple correlation coefficient showed little relationship, and unexpected coefficients appeared (r:-0.613 between height and performance). The multiple regression analysis was of little significance in explaining the variance between the variables and the performance. Some questions can be raised about the analysis:

1) in the multiple regression analysis of circumference category, why was the highest simple correlation not the first one to be inserted?
2) Why were the defensemen eliminated, thereby reducing the sample (junior:12, professional:11)?

Furthermore, the significance tests for the correlation coefficients were not presented, all of the variables were not grouped, and only one regression analysis was not done; the performance variable defined previously is probably not the most reliable variable for the "real" performance, i.e., the defensive players will almost get a lower ratio since they are less offensively minded, and the study analyzed more variables (60) than subjects (36).

Jobin (1975) evaluated the effectiveness of a battery of ice hockey skills tests in predicting ice hockey performance, and compared the battery

with two other batteries of tests not related to ice hockey. The sample consisted of 14 boys eight years of age. The coach rated the performance of the players. Multiple regression equations were computed for each battery of tests, and by regrouping the three batteries of tests the best prediction equation was produced. None of the above equations produced a significant multiple R at the 90% level of probability, except for the equation composed of the best single prodictors from the three batteries (R:0.81). One of the reasons for not obtaining a significant R was the small number of subjects (N:14). Because of this limitation an R:0.79 was not significant at the 90% level of probability.

Finally, Houston and Green (1976) examined selected physiological and anthropometrical characteristics of young (average age: 17.8 to 21.3 years) ice hockey players representing two elite amateur ice hockey leagues. The authors mentioned that 48 players were evaluated. However, in referring to the results section the number of subjects ranged from 23 to 52. Players in both leagues were compared and characteristics of athletes by positions were also examined. There were no major distinctions between the two groups of players on many of the performance criteria studied:

> "The absence of significant physiological differences between the two teams studied emphasized the fact that physiological criteria were not differentiating factors between the two hockey leagues. As played in Canada, at least, hockey is a skill oriented game, where primary emphasis is placed on such things as shooting, passing and puck control." (Houston and Green, 1976)

Summary

Studies in the field of ice hockey have analyzed different player attributes. Analyses of skills, physiological and anthropometrical components have been undertaken both to understand the role of a specific component of ice hockey and to investigate the performance aspects. Some studies (Jobin, 1975; Bouchard et al., 1974; and Houston and Green, 1976) have tried to predict the interaction of one or two of the components with performance, but no study has ever tried to analyze the components making up a typical ice hockey player without regard to the performance aspect. No study has attempted to identify the relationship between three components of the sport, skating skill, physiological and anthropometrical measures.

B. Factor analysis.

1. Common factor analysis.

It is not the purpose of the study to review the statistical and mathematical aspect of "common factor analysis". The readers are referred to Mulaik, S.A.: The Foundations of Factor Analysis, McGraw-Hill Book Co., Montréal, 1972.

2. Factor analysis in physical education research.

The literature reviewed for this section is not an exhaustive one, the main reason being that only some examples of the different areas of physical education using factor analysis will be presented. Table 4 sum-

TABLE 4

Factor analysis methods in physical education.

Studies	Methods[a]	Rotation[b]	N	N of variables
A. Skills				
Hopkins - 1977	1,2,3,4	1,2	70	21
Safrit - ¢968	1,2,3,4	1,2	166	25
Highmore - 1956	5,6		240	14
B. Strength				
Liba - 1967	1,3,4,7	1,2	52	29
Jackson - 1971	4	2	76	
	1,2,3		25	
Jackson and Frankiewicz - 1975	1,2	2	50	16
C. Flexibility and physical fitness				
Harris - 1969	1,2,7,8	1,2	147	53
Baumgartner and Zuidema - 1972	1,2,3,4	1,2	619	13
Liemohn and Knapczyk - 1974	9	2	60	10
Liemohn and Knapczyk - 1974b	1,2,4,10,11	2	93	35
Zuidema and Baumgartner - 1974	1,2,3,4	1,2	206	13
D. Retarded children				
Dobbins and Rurick - 1975	1,2,4	1,2	71	47
Kinney - 1979	1	1	94	25

a - Methods: 1 - alpha; 2 - canon; 3 - image; 4 - princ. comp.; 5 - centroid; 6 - Holzinger; 7 - Joreskog; 8 - Harris; 9 - multifact.; 10 - princ. fact.; 11 - min. res.

b - Rotation: 1 - oblique; 2 - orthogonal

marizes some of the research done in physical education.

It is particularly important to note the general trend towards the use of as many methods as possible for analyzing the data and also the use of two rotation procedures (Liba, 1967; Safrit, 1968; Harris, 1969; Jackson, 1971; Baumgartner and Zuidema, 1972; Baumgartner, 1974; Liehmon and Knapczyk, 1974b; and Dobbins and Rurick, 1975). The ratio of the number of subjects to the number of variables is an aspect that should be considered. Some of the studies presented a very low ratio (Liba, 1967; Jackson, 1971; Dobbins and Rurick, 1975).

Summary.

Factor analysis is not a new method of analyzing data in physical education but the rationale for the use of a specific factor analysis method is rarely presented; seemingly most researchers take a chance, hoping that one of the eight or nine combinations (method and rotation) used will be able to be interpreted.

CHAPTER III

METHODOLOGY

This chapter describes the skating skill tests, the physiological tests, and the anthropometrical measurements used in the present study, as well as the general procedure for the on-ice and in-lab tests. The sample, as previously described (Chapter I, Sample), consisted of 187 ice hockey players aged 13 to 16 years. All these players competed in the Saguenay-Lac-Saint-Jean region at the "AA" level of competition. The 187 players who participated in the testing were all volunteers.

A. Skating skills tests.

The tests are presented in table 5. They are divided into three sections: speed skating, agility skating (with and without a puck), and endurance skating.

1. Speed tests. (Hansen et al., 1970).

The purpose of these tests was to measure skating speed in seconds as the subjects skated forward and backward over 90 feet and 120 feet. The subjects skated in a straight line as fast as possible from the backboard at one end of the rink passed the second blue line, 120 feet away. A cone was placed 20 feet beyond the second blue line as a reference point at which the subject began his deceleration in order to stop before reaching the end boards. This marker was placed beyond the second blue line so that the subject would skate as fast as possible until he crossed the finish line.

TABLE 5

Test measuring skating skill.

Tests[1]	Description
Speed tests[a]	90 feet forward
	120 feet forward
	90 feet backward
	120 feet backward
Agility tests[b]	Marcotte
	Hansen
	Without a puck
	Backward
Endurance[c]	8 minutes continuous skating

1. a) Hansen et *al*. (1970).
   b) Macnab (1979).
   c) Larivière et *al*. (1976).

[illegible]

[illegible]

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The goalcrease line at the nearest end of the rink represented the starting line. The red line was 90 feet and the second blue line was 120 feet from the starting line. These lines are common to all ice hockey surfaces and do not vary if the surface is built according to C.A.H.A. standards. In the case of varying dimensions, appropriate adjustments were made in measuring the 90 and 120 feet distance and in marking new lines.

The procedure of the test was explained to all subjects before the test began. A demonstration by an assistant was provided when necessary. Each subject started with one hand touching the backboard. Subjects were told to skate as fast as possible and in a straight line past the far blue line, then to decelerate at the cone placed 20 feet past the blue line and to stop as they approached the backboard. The commands "Ready - Go" were given and the subject began the test.

Time to the nearest tenth of a second was recorded for each subject as he skated past the 90 and 120 feet marker, respectively. The time began as the subject's foot touched the starting line (the goalcrease line at one end of the rink). Readings at 90 feet and 120 feet were taken as the subject's foot touched or began to cross each line. Eight timers were stationed on the ice in a position where full view of the subject's skating action over 120 feet could be seen. The subjects were sent in pairs. Each distance was monitored by two timers and the average of the two times was recorded.

[illegible]

[illegible]

[illegible]

2. Agility tests. (Macnab, 1979).

a) Marcotte's test (modified in the Macnab study).

The purpose of the test was to measure the time required by a subject to skate through the test course, as described below, while maintaining control of a puck.

From a standing start with both skates on the goalcrease line, the subject skated towards cone 1 (Figure 1) and made a quick stop, changed direction towards cone 2 and then made a right turn, weaved through cones 3, 4 and 5 (20 feet apart), and skated in a staight line as fast as possible back to the goalcrease line.

Once an explanation and demonstration were given the subject executed the test with puck and stick. The subject was instructed to repeat the test if he did not execute it properly. Time began as the subject's feet crossed the starting line and stopped as the subject's feet touched the finish line. The average of the two times was recorded to the nearest tenth of a second for each subject.

b) Agility test without a puck.

The purpose of the test was to measure the time required for a subject to skate an agility course as described below.

From a standing start, with both skates on the red line and with his back facing cone 1 (Figure 1) placed three feet directly behind him,

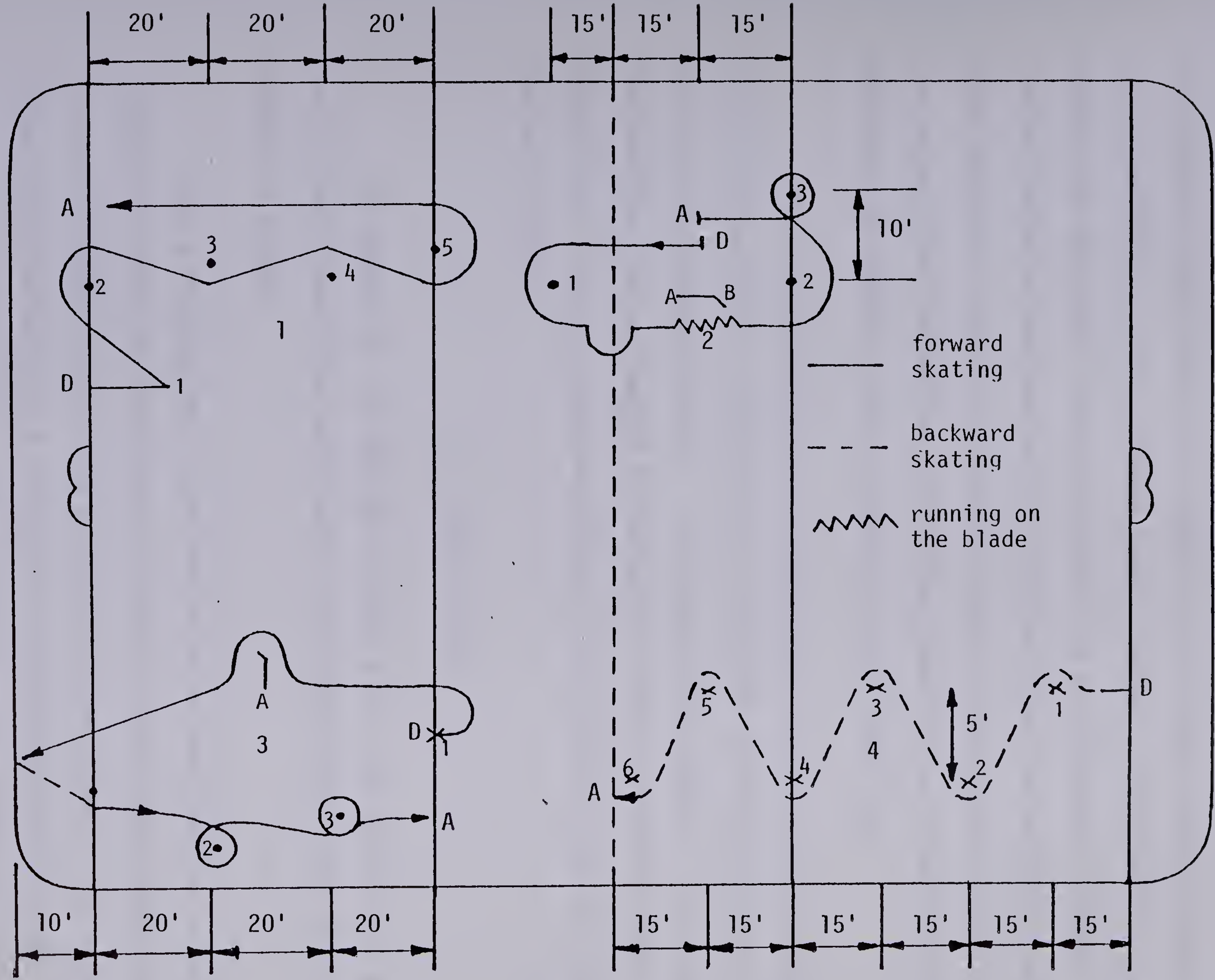

FIGURE 1 - Diagram representing the on-ice tests:
1) Marcotte 2) Agility without a puck 3) Hansen 4) Backward agility.

the subject turned either to his right or left, skated forward around the above mentioned cone and proceeded toward a hockey stick placed half way between the red center line and the blue line as indicated in figure 1. The subject skated on the front part of his blade (ran) from point A to point B (the length of a hockey stick) after he made his turn around cones 2 and 3. The subject then touched the ice with one glove at a point one foot outside each cone and skated as fast as possible to the finish line.

After an explanation and a demonstration the subject executed the test without a stick. The subject was instructed to repeat the test if the test was not executed properly. Time began as the subject's feet crossed the starting line and stopped as the subject's feet touched the finish line. The average of the two times was recorded to the nearest tenth of a second for each subject.

c) Hansen's test.

The purpose of the test was to measure the time required for a subject to skate through the test course as described below, while maintaining control of a puck.

From a standing start with both skates on the blue line, a puck between his skates and facing cone 1 (Figure 1), the subject began the test by kicking the puck to his stick as he skated toward cone 1. The subject turned around the cone, in a clockwise or counterclockwise direction, according to his preference, and he skated toward the stick, (point A).

The subject then had to carry the puck around the stick as he jumped or stepped over it. Once the subject crossed the stick which was mid-way between the goalcrease line and the blue line (30 feet), he continued to the endboards, stopped, skated backwards to the goalcrease line, turned to his left and skated around cone 2, proceeded to cone 3, skated around it in a reverse direction to his pattern at cone 2, then proceeded to the finish line.

The test proceeded immediately after an explanation and a demonstration. Mistrials were repeated when the group was finished. Subjects were directed to skate as quickly as possible while keeping control of the puck. Subjects were also advised to put one hand on the stick while crossing the hockey stick. Watches were started on the command "Go". The watches stopped as the first skate crossed the finish line. The average of two times to the nearest tenth of a second was recorded as the subject's score.

d) Backward agility test.

The purpose of the test was to measure the time required for a subject to skate backward through the test course as described below.

From a standing start, facing the endboards, with both skates on the goalcrease line, the subject weaved through cone 1 (Figure 1) to cone 6 as fast as possible up to the red centre line (90 feet from the starting point).

Execution of the test proceeded after an explanation and a demonstration. Mistrials were repeated when all the group was finished. Subjects were instructed to skate as quickly as possible through the course. Time began as the subject's feet crossed the goalcrease line and stopped as the subject's feet touched the finish line. The average of two times was recorded to the nearest tenth of a second for each subject.

3. Endurance test (Larivière et al., 1976).

a) Eight minutes of continuous skating.

Endurance was determined by measuring the distance (meters) skated by a subject during an eight minute interval.

The ice surface was divided into ten unequal distances (Figure 2). The distance was recorded after eight minutes to the nearest cone on the ice.

B) Physiological measurements and predictions.

The measurements taken and the predictions made were:

1. Aerobic tests:

a) physical work capacity 170 (PWC_{170}),

b) PWC_{170}/weight,

c) VO_2 max. (predicted), and

d) VO_2 max, / weight.

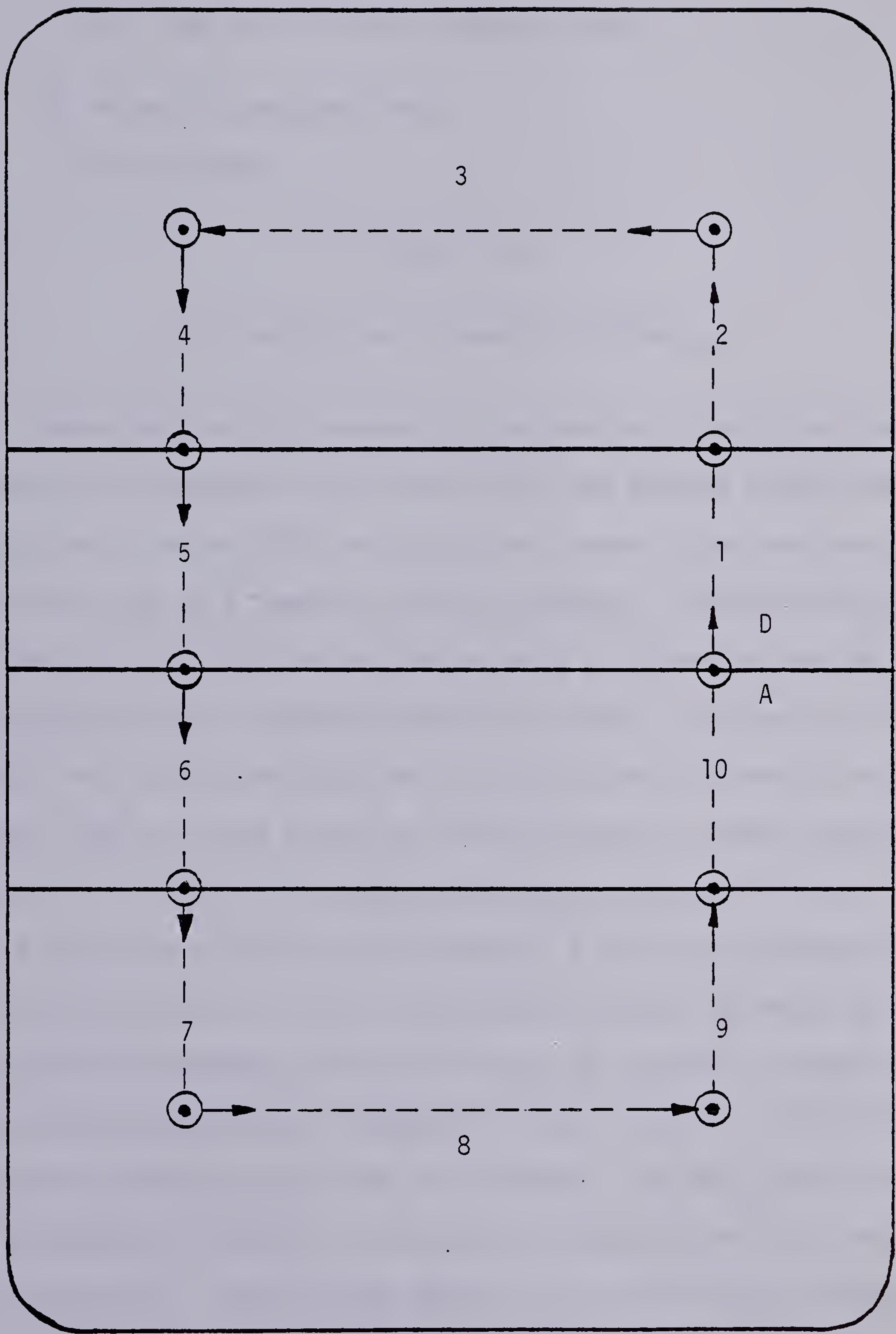

FIGURE 2 - Eight minutes of continuous skating test.

2. Leg test:

a) jump and reach test (Sargeant test)

3) Abdominal endurance test:

a) sit-ups.

1. Aerobic tests.

a) Physical work capacity 170 (PWC_{170}).

The actual test for determining the working capacity was performed according to the method of Sjostrand (1947), and Wahlund (1948) with some modifications. In the test, the subject was asked to perform three consecutive work loads on a "Monark" bicycle ergometer. The pedalling rate was maintained at 60 revolutions per minute using a tachometer, and the work load of pedalling was increased every four minutes. For one out of three subjects, the rate of pedalling was also registered by a mechanical counter. The heart rate was taken during the last 20 seconds of every minute of exercise, on an E.C.G.. An attempt was made to schedule the work loads of each subject so that the first load produced a heart rate between 100 and 120 beats per minute, the second load between 120 and 140 beats per minute, and the third load between 150 and 170 beats per minute. The pedal-seat relationship was individually adjusted for each subject so that differences in mechanical advantage were kept to a minimum. The PWC_{170} was calculated using a regression equation of the heart rate against the work load, at the end of each trial. The estimated amount of power that would produce a heart rate of 170 beats per minute was then recorded as the PWC_{170} of that indi-

vidual (Adams et al., 1961).

b) Physical work capacity / weight.

The result obtained for the PWC_{170} was then divided by the body weight of the subject and recorded as his PWC_{170}/kg.

c) Maximal oxygen uptake (VO_2max.).

Using the monogram developed by Astrand and Rythming (1954) a prediction of the oxygen uptake was obtained for each subject and recorded.

d) Maximal oxygen uptake / weight.

The result obtained for the maximal oxygen uptake was then divided by the body weight of the subject to obtain an uptake known as VO_2max. (ml./kg.min.).

2. Leg test.

a) Jump and reach test (Sargeant test).

The procedure for the test was taken from Sargeant (1946). Each subject had to jump as high as possible and the difference between the maximal height jumped and the standing height (with arm extended over the head) was recorded. The test measured not only leg power but mostly the subject's ability to jump, and his motivation to jump.

3. Abdominal endurance test.

a) Sit-ups.

The maximum number of sit-ups, the knees bended and the arms behind the neck, during one minute was recorded as the result for each subject.

C. Anthropometrical measures.

The measures were divided into eight sections:

1. Body lengths:

   a) upper arm,
   b) forearm,
   c) leg, and
   d) lower leg.

2. Body circumferences:

   a) upper arm,
   b) forearm,
   c) wrist,
   d) leg, and
   e) lower leg.

3. Body widths:

   a) bi-acromial, and
   b) bi-trochanter.

4. Skinfolds:

   a) triceps,
   b) sub-scapular,
   c) mid-axilla,
   d) chest,
   e) abdomen, and
   f) supra-iliac.

5. Body fat.

6. Weight.

7. Height.

8. Age.

Each anthropometrical measure was taken twice, except for the age at each site, and the average of the two measures was recorded. The measurements were registered in millimeters. The reference for the determination of the sites for the anthropometrical measures was: Wells, K.F., Kinesiology, 3rd ed., W.B. Saunder Co., Phil. 1963.

1. Body lengths.

a) Upper arm: distance from the greater tuberosity of the humerus to the mid-point of the olecranon process of the elbow; while the elbow was flexed to 90 degrees.

b) Forearm: distance measured from the mid-point of the olecranon process of the elbow to the styloid process of the ulna.

c) Leg: distance measures from the mid-point of the greater trochanter of the femur to the lateral joint line of the knee.

d) Lower leg: distance measured from the lateral joint of the knee to the mid-point of the lateral malleolus.

2. Body circumferences.

a) Upper arm: circumference measured at mid-belly of the biceps.

b) Forearm: circumference measured at mid-point from the origin to the flexor muscle-tendon junction, generally.

c) Wrist: circumference measured at the radial and ulnar styloid processes.

d) Leg: circumference measured at mid-belly of the quadriceps.

e) Lower leg: circumference measured at the mid-point from the origin of triceps surae to the muscle-tendon junction, generally.

3. Body widths.

a) Bi-acromial: distance measured between tips of the acromions.

b) Bi-trochanter: distance measured between the mid-points of the trochanters.

4. Skinfolds.

a) Triceps: taken at mid-points of the triceps.

b) Sub-scapular: taken at the inferior angle of the scapula.

c) Mid-axilla: taken on the lateral aspect of the chest at the nipple line.

d) Chest: taken on the anterior aspect of the chest immediately below the nipple line.

e) Abdomen: taken on the anterior aspect of the abdomen lateral to the umbilicus.

f) Supra-iliac: taken immediately superior to the iliac crest.

5. Body fat.

The percentage of fat was determined by using two prediction formulae. First, from the skinfold measures, the body density was predicted using the Pascale et al. (1956) formula and from the density results obtained, the percentage of body fat was predicted using the Brozek (1963) formula.

Density: $1.088468 - 0.007123X_1 - 0.004834X_2 - 0.005513X_3$

X_1: mid-axilla skinfold (cm)

X_2: juxta-nipple skinfold (cm)

X_3: triceps skinfold (cm)

% body fat: ((4.57 / density) - 4.142) x 100.

6. Weight.

The weight of every subject was recorded in kilograms using a DETECTO balance.

7. Height.

The height of every subject was recorded in centimeters using a DETECTO balance.

8. Age.

The age of every subject was calculated to the nearest month.

D. General procedure.

On-ice tests were administered during practice hours of each team on their own ice surface. The entire team executed the speed tests as described previously. The team was then divided into four groups for the execution of the four agility tests. A rotation was made when the four groups accomplished a test. Subsequently, the team was divided into two groups for the endurance test, each player being assigned to another and counting the laps of his partner. In general, a period varying from an hour and a half to two hours was sufficient to measure an entire team.

The laboratory tests were administered two weeks after the on-ice tests. The players were scheduled three at a time and the measures were taken as follows: weight and height; body lengths, circumferences, widths and skinfolds; leg test and abdominal endurance test. A 15 minute rest period was then given to the subject prior to the PWC_{170} test.

For the training of the timers for the on-ice tests and the assistants for the lab-tests two training periods were scheduled prior to the testing session. During these training sessions, the helpers executed the same tasks on 20 subjects.

CHAPTER IV

RESULTS AND DISCUSSION

A. Results.

The on-ice skating skill measures were obtained for 187 ice hockey players. The results are presented in table 6, subdivided into the three components of skating skill (speed skating, agility and endurance). Subsequent analysis, i.e., dividing the group into two sub-groups (13-14 years) and (15-16 years), was done and the results are presented in table 7 and 8.

Similar summaries for ages, weights, heights, body lengths, body circumferences, body widths, skinfolds, percentage of body fat, sit-ups, jump and reach results, and cardiorespiratory measurements are presented in table 9 for the entire sample, and tables 10 and 11 contain the results for the two sub-groups.

1. Investigation into the sport of ice hockey.

The roots obtained by the principal components analysis, the "scree test", shown in figure 3 suggested an eight factors structure for rotation using the "varimax" procedure. However, only the first four factors were retained. The last four factors were excluded because of a lack of relationship between the variables and these factors. The factor loadings for the four factors retained are presented in table 12, and such structure accounted for 59.7% of the total variance. The first factor, which accounted for 25.4% of the total variance, is composed of the following anthropo-

TABLE 6

Means and standard deviations for on-ice variables;
13 to 16 year old players (N:177 - 132[a])

Variables	Means	S.D.
Skating speed (sec)		
F90	4.53 - 4.57[a]	0.38 - 0.40[a]
BA90	6.08 - 6.11	0.56 - 0.59
F120	5.80 - 5.87	0.59 - 0.61
BA120	7.65 - 7.71	0.75 - 0.81
Skating agility (sec)		
MAR	13.43 - 13.56	1.38 - 1.47
HAN	17.26 - 17.49	1.98 - 2.08
AWP	9.11 - 9.17	1.04 - 1.11
AOI	8.69 - 8.74	1.14 - 1.19
Endurance skating (m)		
AER	2516.26 - 2509.07	264.02 - 277.41

a - Without the goaltenders.

TABLE 7

Means and standard deviations for on-ice variables; 13 and 14 years old players (N:88 - 71[a])

Variables	Means	S.D.
Skating speed (sec)		
F90	4.67 - 4.69[a]	0.37 - 0.40[a]
BA90	6.07 - 6.09	0.55 - 0.57
F120	6.11 - 6.12	0.56 - 0.60
BA120	7.80 - 7.83	0.75 - 0.79
Skating agility (sec)		
MAR	13.67 - 13.76	1.24 - 1.35
HAN	17.29 - 17.51	1.73 - 1.82
AWP	8.75 - 8.84	0.88 - 0.94
AOI	8.41 - 8.47	1.17 - 1.23
Endurance skating (m)		
AER	2512.49 - 2501.81	265.26 - 285.64

a - Without the goaltenders.

TABLE 8

Means and standard deviations for on-ice variables;
15 and 16 years old players (N:88 - 76[a])

Variables	Means	S.D.
Skating speed (sec)		
F90	4.39 - 4.41[a]	0.34 - 0.34[a]
BA90	6.09 - 6.13	0.57 - 0.59
F120	5.49 - 5.52	0.43 - 0.45
BA120	7.51 - 7.52	0.73 - 9.77
Skating agility (sec)		
MAR	13.18 - 13.26	1.46 - 1.53
HAN	17.24 - 17.40	2.20 - 2.29
AWP	9.46 - 9.48	1.07 - 1.13
AOI	8.96 - 8.98	1.05 - 1.10
Endurance skating (m)		
AER	2519.99 - 2516.25	264.24 - 272.44

a - Without the goaltenders.

TABLE 9

Means and standards deviations for laboratory variables; 13 to 16 years old players (N:171 - 142[a])

Variables	Means	S.D.
Age (months)	179.78 - 179.90[a]	13.19 - 13.27[a]
Weight (kg)	60.90 - 61.76	9.62 - 9.10
Height (cm)	168.67 - 169.44	7.40 - 6.80
Body lengths (mm)		
LFA	279.76 - 280.80	19.75 - 19.63
LAR	243.02 - 244.53	18.33 - 18.27
LLE	391.52 - 391.46	40.00 - 39.00
LLL	404.08 - 406.89	31.48 - 31.76
Body circumferences (mm)		
CAR	264.02 - 265.52	24.76 - 24.62
CFA	251.42 - 252.60	18.99 - 18.22
CWR	171.98 - 172.66	8.73 - 8.29
CLE	500.76 - 503.26	40.33 - 33.32
CLL	343.00 - 345.14	24.41 - 23.35
Body widths (mm)		
BIAC	337.57 - 339.48	29.59 - 29.00
BITR	300.76 - 301.67	30.57 - 30.47
Skinfolds (mm)		
TRI	7.95 - 8.11	2.01 - 2.05
SUB	8.26 - 8.38	2.17 - 2.15
MID	6.63 - 6.76	1.01 - 1.96
CHE	6.77 - 6.95	2.07 - 2.13
ABD	9.43 - 9.63	3.87 - 3.74
SUP	8.35 - 8.50	3.75 - 3.74
Body fat (%)	10.02 - 10.14	1.32 - 1.36
Sit-ups (#)	45.85 - 45.72	6.11 - 6.14
Jump @ reach (in)	17.43 - 17.46	3.10 - 3.13
Cardirespiratory measures		
PWC_{170}(kpm/min)	802.68 - 809.07	236.05 - 235.28
PWC_{170}/kg	13.17 - 13.13	3.43 - 3.46
VO_2 (l/min)	2.47 - 2.49	0.59 - 0.58
VO_2/kg	40.71 - 40.53	9.12 - 9.16

a - Without the goaltenders.

TABLE 10

Means and standard deviations for laboratory variables; 13 and 14 years old players (N:88 - 71[a]).

Variables	Means	S.D.
Age (months)	168.81 - 168.70[a]	6.23 - 6.49[a]
Weight (kg)	56.61 - 57.96	9.13 - 8.97
Height (cm)	¢65.30 - 166.56	7.44 - 7.13
Body lengths (mm)		
LFA	275.91 - 278.56	19.07 - 18.88
LAR	237.25 - 239.07	18.25 - 18.68
LLE	393.38 - 391.46	47.49 - 47.16
LLL	394.80 - 397.97	29.80 - 30.36
Body circumferences (mm)		
CAR	253.44 - 255.97	22.63 - 22.76
CFA	243.58 - 245.82	18.06 - 17.86
CWR	168.38 - 169.43	8.84 - 8.47
CLE	481.80 - 485.97	37.49 - 35.47
CLL	335.13 - 338.25	22.07 - 20.65
Body widths (mm)		
BIAC	340.90 - 345.52	35.17 - 34.15
BITR	388.59 - 388.91	32.16 - 31.98
Skinfolds (mm)		
TRI	8.21 - 8.39	2.05 - 2.09
SUB	7.70 - 7.93	1.89 - 1.93
MID	6.42 - 6.66	1.81 - 1.87
CHE	6.95 - 7.21	2.15 - 2.24
ABD	9.16 - 9.57	3.65 - 3.79
SUP	7.66 - 7.93	2.57 - 2.63
Body fat (%)	10.03 - 10.19	1.34 - 1.38
Sit-ups (#)	46.95 - 46.67	5.74 - 5.92
Jump @ reach (in)	15.86 - 15.86	2.53 - 2.59
Cardiorespiratory measures		
PWC_{170} (kpm/min)	681.16 - 690.27	229.89 - 228.47
PWC_{170}/kg	12.02 - 11.94	3.68 - 3.69
VO_2 max. (l/min)	2.26 - 2.29	0.61 - 0.60
VO_2 max./kg	40.21 - 39.92	10.29 - 10.34

a - Without the goaltenders.

[illegible]

TABLE 11

Means and standard deviations for laboratory variables; 15 and 16 years old players (N:83 - 71[a])

Variables	Means	S.D.
Age (months)	191.40 - 191.10[a]	7.35 - 7.62[a]
Weight (kg)	65.13 - 65.34	8.13 - 7.70
Height (cm)	171.99 - 172.15	5.68 - 5.21
Body lengths (mm)		
LFA	283.51 - 282.91	19.78 - 20.21
LAR	248.64 - 249.68	16.67 - 16.40
LLE	389.70 - 391.45	41.21 - 39.65
LLL	413.14 - 415.31	30.57 - 30.93
Body circumferences (mm)		
CAR	274.34 - 274.53	22.39 - 22.97
CFA	259.17 - 259.08	16.64 - 16.18
CWR	175.54 - 175.74	7.03 - 6.86
CLE	519.26 - 519.58	34.05 - 33.64
CLL	350.67 - 351.63	24.25 - 24.01
Body widths (mm)		
BIAC	334.32 - 333.77	22.62 - 21.88
BITR	312.64 - 313.70	23.65 - 23.46
Skinfolds (mm)		
TRI	7.68 - 7.84	1.95 - 9.99
SUB	8.81 - 8.81	2.30 - 2.28
MID	6.83 - 6.86	1.99 - 2.05
CHE	6.58 - 6.70	1.99 - 2.00
ABD	9.70 - 9.68	4.07 - 4.05
SUP	9.02 - 9.03	4.53 - 4.50
Body fat (%)	10.01 - 10.08	1.31 - 1.34
Sit-ups (#)	44.74 - 44.78	6.30 - 6.25
Jump @ reach (in)	18.95 - 18.97	2.84 - 2.84
Cardiorespiratory measures		
PWC_{170} (kpm/min)	918.34 - 919.50	177.09 - 182.76
PWC_{170}/kg	14.27 - 14.24	2.77 - 2.82
VO_2 max. (l/min)	2.67 - 2.68	0.48 - 0.49
VO_2/kg	41.18 - 41.10	7.87 - 7.95

a - Without the goaltenders.

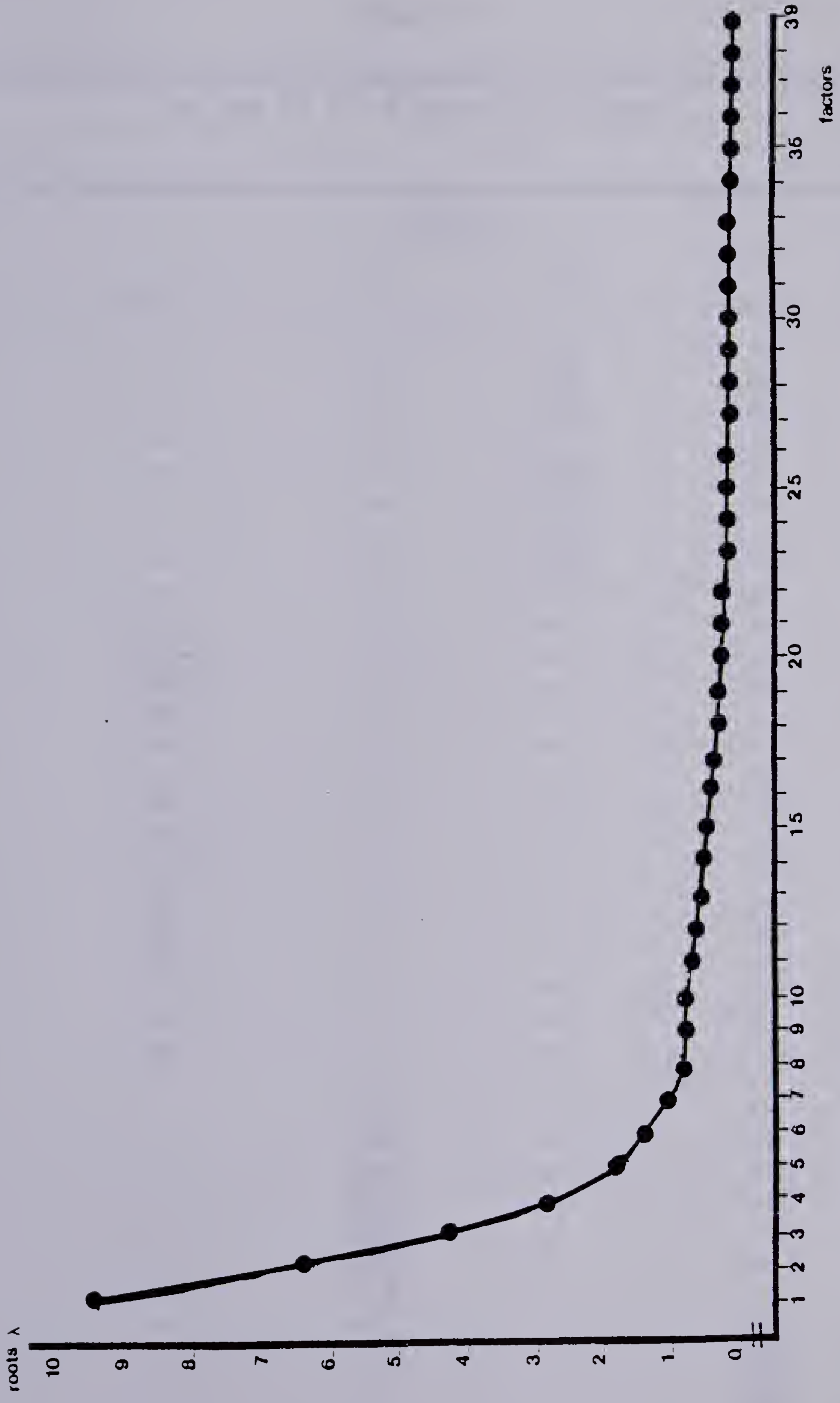

FIGURE 3 - Scree test.

TABLE 12

Factor analysis (principal components, with the varimax rotation) for the 13 to 16 years old players.

Variables	Factors I	II	III	IV	H^2
F90	—	—	.664	—	.590
BA90	—	—	.712	—	.532
F120	—	—	.656	—	.604
BA120	—	—	.811	—	.693
MAR	—	—	.800	—	.688
HAN	—	—	.718	—	.530
AWP	—	—	.777	—	.654
AOI	—	—	.638	—	.538
AER	—	—	-.619	—	.413
AGE	.624	—	—	—	.434
WEI	.856	—	—	—	.938
HEI	.848	—	—	—	.733
LFA	.440	—	—	—	.250
LAR	.599	—	—	—	.365
LLE	—	—	—	—	.077
LLL	.566	—	—	—	.327
CAR	.650	—	—	—	.751
CFA	.710	—	—	—	.666
CWR	.787	—	—	—	.670
CLE	.692	—	—	—	.733
CLL	.622	—	—	—	.524
BIAC	—	—	—	—	.072
BITR	.547	—	—	—	.439
JAR	.554	—	—	—	.352
SIT	—	—	—	—	.043
TRI	—	.731	—	—	.594
SUB	—	.752	—	—	.663
MID	—	.850	—	—	.767
CHE	—	.874	—	—	.778
ABD	—	.839	—	—	.732
SUP	—	.673	—	—	.468
PBF	—	.975	—	—	.977
PWC	—	—	—	.856	.973
PWCW	—	—	—	.958	.964
VO2	—	—	—	.882	.946
VO2W	—	—	—	.939	.966
Variance	25.4%	42.8%	52.8%	59.7%	

metrical measures: weight, height, four of the five body length measures, the five body circumference measures, one of the two body width measures, and age. The jump and reach test is also loaded under the first factor. The highest loadings for factor I were the weight and the height loadings (0.856 and 0.848, respectively).

The second factor, which accounted for 17.4% of the total variance, is composed of the six skinfold measures, and one linear component of the skinfold measures; the percentage of body fat. Without regard to the percentage of body fat loading (.975) the highest loadings were chest and mid-axilla skinfold measures (0.874 and 0.850, respectively).

The third factor, which accounted for 10.0% of the total variance, is composed of skating skill variables (tests); the four speed skating tests, the four agility skating tests and the endurance skating test. The skating speed test, backward 120 feet, and Marcotte's agility test have the highest loadings for factor III (0.811 and 0.800, respectively).

Finally, the fourth factor, which accounted for 6.9% of the total variance, is composed of the four cardiorespiratory measures and predictions. The highest loadings were the maximal oxygen uptake corrected for weight, and the physical work capacity (PWC_{170}) corrected for weight (0.939 and 0.958, respectively).

Each variable was considered to belong to the factor to which it was most strongly related (age belonging to the first factor because of its highest relationship; 0.624, was found with factor I). An arbitary

loading of 0.50 was considered as a criterion value for the inclusion of a variable under a factor (except at the upper arm lenght variable, LFA, where 0.44 was the criterion). Table 12 shows all the variables that had a single high loading under one factor. Three variables, leg length (LLE), bi-acromial width (BIAC), and sit-ups (SIT), did not load under any four of the factors and their communalities (h^2) were very low (0.077, 0.072 and 0.040, respectively).

2. Comparison of the sub-groups.

The comparison of the two sub-groups (13-14 years and 15-16 years) was made on the component score means for the four factors retained by the principal components analysis. Hotelling's T^2, as shown in table 13, was 88.64 ($p < .05$).

Since the components are independent, four "student"-t tests (two sample t-test) were conducted on the means of the four factors to determine which factor showed a significant difference between the means of the two sub-groups. As reported in table 13, difference between means were found on one factor at the 0.01 level of significance; on factor I (anthropometrical measures), sub-group II had a higher mean then sub-group I on the factor scores (0.669 and -0.601; t= -8.57).

TABLE 13

Means of the factor scores for the two sub-groups, Hotelling's T^2 and two sample t-test ("student").

1.	<u>Means</u>	Sub-group I	Sub-group II	Diff.
	I (anthrop.)	-.601	.669	1.27
	II (skinfolds)	-.061	-.178	0.239
	III (skating)	-.023	-.012	0.011
	IV (cardio.)	-.113	.231	0.334
2.	<u>Hotelling's T^2</u>	T^2	F	Df
		88.64	21.69*	4.138
3.	<u>Student t-tests</u>	Factors	t	
		I	-8.57**	
		II	1.48	
		III	-0.06	
		IV	-1.97	

* p (α =.05), F(4,150)= 2.37.

** p (α =.01), t(200) = 2.33.

B. Discussion

1. Investigation into the sport of ice hockey.

From the principal components analysis, four factors emerged from the ice hockey permormance of players 13 to 16 years of age. These factors were labeled: anthropometrical, skinfolds, skating "skill"tests, and cardiorespiratory measures and predictions factors. When compared with the theoretical structure of three factors (anthropometrical, physiological and skating "skill" tests component) the results confirmed partially the theoretical structure, and divided the anthropometrical factor into two distinct factors: anthropometrical and skinfolds factors. The skating skill tests factor and the cardiorespiratory measures and predictions factors were found in their entirety (all six skating skill variables (tests) loaded under the same factor, and all four cardiorespiratory measures and predictions variables loaded under the same factor).

The findings of the skating skill tests factor makes possible the assertion that ice hockey is a sport where the specificity of the skill, measured by the tests, involves a factor independent from all other components. Such a statement contradicts, in part, the statements of some researchers, coaches, and recruiters (scouts) who have declared that weight, height or any other physiological and anthropometrical components are predictive variables for ice hockey skills. But, as mentioned previously, the variables loading under that factor are all measured by a specific test; one should be aware of the limitations of such tests (further discussion

is reported in the following section: Limitations of the skating skill tests).

The present research has demonstrated that a way to recognize an ice hockey player is to measure his on-ice performance. The skating skill tests factor was a good indicator of the specificity of ice hockey because all six skating skill variables (tests) were loaded under only one factor. Therefore the decision for naming such a factor became very simple because the relationship of the six variables (tests) with the three other factors were almost non-existant.

Concerning the theoretical anthropometrical factor, the study has shown that the anthropometrical factor is divided into two independent components: anthropometrical measures, and skinfold measures. The anthropometrical factor accounted for most of the variance (25.4%). Most of the anthropometrical measures were found under this factor, the exception being length of the leg, and bi-acromial width. The jump and reach variable was also found under the anthropometrical factor. There seems to be no explanation for such a phenomenon save that the height, weight, and anthropometrical variables make up the jump and reach test from a linear combination of their values. All the higher coefficients of correlation for the jump and reach test are related with the previous variable (Appendix A).

The skinfold factor was not a theoretical factor. Instead, all measures were expected to be found under the theoretical anthropometrical factor. The independence of such a factor concerning the anthropometrical variables may explain such a result. For example, a skinfold variable is

not associated with leght, width, or circumference of body segments. Another explanation for the split of the theoretical anthropometrical factor may reside in the propriety of the sample.

The last theoretical factor was the physiological factor. This factor was found and labeled: cardiorespiratory measures and predictions factor. Discussion of the factor must be limited because two of the four variables of the factor are linear components of the PWC_{170} and the PWC_{170} divided by the body weight. It can only be said that the independence between the cardiorespiratory system, as measured by the PWC_{170}, and the other factors (skating skill tests, anthropometrical, and skinfold) tended to be demonstrated.

Summary.

The study found four factors involved in the performance of ice hockey players: anthropometrical, skinflod, skating skill tests, and cardiorespiratory factors. When compared with the three theoretical factors (anthropometrical, physiological and skating skill tests), these four factors confirmed in part the theoretical factors and clarified the anthropometrical factor by dividing it into two parts: anthropometrical, and skinfold factors.

The discovery of the skating skill tests factor is a step towards a better understanding of the ice hockey player. Such a factor indicates the independence of the skating skill tests from anthropometrical, and

[illegible]

physiological components for this select group. Thus, the specificity of ice hockey concerning other physical activities is confirmed, if we accept the assumption that the tests used in measuring the skills are in effect valid tests for the skills.

2. The structural validity of the skating skill tests.

The structural validity of the skating skill tests measuring speed, agility, and endurance was examined to discover the structure of the components used in the skating skill tests factor. The third factor extracted by the principal components analysis is called the skating skill tests factor because all the six variables (tests) measuring the skills loaded on this third factor. The loadings are interpreted as the degree of relationship between each variable and the factor. In this study, the six skating skill variables (tests) were highly related to the skating skill tests factor, ranging from -0.610 for the endurance test to 0.811 for the 120 foot backward speed test (table 12). A comparison between the validity (reported in the review of the literature; table 3) and the structural validity of the tests reported in this study can be made. For the forward speed test, 120 feet, Merrifield and Walford (1969, 1971) reported validity coefficients ranging from r= 0.69 to 0.83. In the present study, the loading of the test on the third factor is 0.656. For the backward speed test, (120 feet) the previous authors reported validity coefficients ranging from r= 0.64 to 0.79. The present study reported a coefficient (loading) of 0.811. For the Marcotte agility test, Doruschuck and Marcotte (1966) reported a validity coefficient of r= 0.83, while this study found a co-

[illegible]

[illegible]

[illegible]

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efficient of 0.800. Larivière et al. (1976) reported a validity coefficient of r: 0.79 for the endurance test, while the present study found a coefficient (loading) of -0.619. Previous studies obtained validity coefficients by finding the relationship between the ranking of the players on their skills (by the coaches or experts), and the actual on-ice performance for the test. In this study, the structural validity of the components of the factor is judged on the potentiality of the tests (as an ensemble) to load under the skating skill tests factor. For those tests for which validity coefficients were available, the present study show a relationship close to the coefficients reported in the literature.

Summary.

The structural validity of the components (tests) of the factor found in the present study, has been shown to be accurate because the six skating skill tests had a good relationship with the factor, and when compared with previous validity studies. These relationships were in the same range as the ones reported in this study. The skating skill tests factor gives information about the utility of the tests used in measuring such skills.

3. Comparison of the factor scores for the two sub-groups.

One of the purpose of the study was to examine the different sub-groups ("bantam": 13 and 14 years, and "midget": 15 and 16 years) to detect possible differentiating elements. The factor components of every individual who completed all the measurements were computed for the four factors

found by the principal components analysis.

It is important to note that the factor structures for the two sub-groups (Table 14, 15, 16, and 17; and Appendices B and C) combined the variables to create structures similar to the ones presented in table 12, for the group. The rationale behind the similitude for the three different factor structures (one for the group and one for each sub-group) can be explained by a coefficient of agreement between the variable loadings for one factor for the entire group in comparison with the same factor for each of the sub-groups. The four coefficients for the four factors (anthropometrical, skinfold, skating skill tests, and cardiorespiratory) are found in tables 14, 15, 16, and 17. As observed they varied from 61.5% to 157.1% of agreement. These coefficients are reasonably high and it is possible to conclude that the structures for the two sub-groups are almost identical to the entire group.

The results presented in table 13 showed a difference between the component scores for the two sub-groups (Hotelling's T^2). Further analyses showed on which factors these differences were significant. The Student-t tests found one factor showing differences the anthropometrical factor. Such differences for the anthropometrical factor was expected, the subject's age being in the range where the growth and development of the human body is still an important aspect.

No differences between the two sub-groups were found for the skinfold, cardiorespiratory, and skating skill tests factors. The result for

TABLE 14

Coefficients of agreement for the anthropometrical factor (group and sub-groups).

	Group	Sub-group I	Sub-group II
1.	AGE	AGE	AGE*
2.	WEI	WEI	WEI
3.	HEI	HEI	HEI
4.	FLA	LFA	——
5.	LAR	LAR	LAR
6.	——	——	LLU*
7.	LLL	LLL	LLL
8.	CAR	CAR	CAR*
9.	CFA	CFA	CFA
10.	CWR	CWR	CWR
11.	CLE	CLE	CLE*
12.	CLL	CLL	CLL
13.	——	——	BIAC
14.	BITR	BITR	——
15.	JAR	——	JAR
Agreement:			
	100%	92.3%	61.5%
			84.6%

TABLE 15

Coefficients of agreement for the skinfold factor.

Group	Sub-group I	Sub-group II
1. TRI	TRI	TRI
2. SUB	SUB	SUB
3. MID	MID	MID
4. CHE	CHE	CHE
5. ABD	ABD	ABD
6. SUP	SUP	SUP
7. PBF	PBF	PBF
8. ——	——	LFA
9. ——	——	CAB*
10. ——	——	CLE*
11. ——	——	BITR
Agreement:		
100%	100%	157.1%
		128.6%

TABLE 16

Coefficients of agreement for the skating skill tests factor.

	Group	Sub-group I	Sub-group II
1.	F90	F90	F90
2.	BA90	BA90	BA90
3.	F120	F120	F120
4.	BA120	BA120	BA120
5.	MAR	MAR	MAR
6.	HAN	HAN	HAN
7.	AWP	AWP	AWP
8.	AOI	AOI	AOI
9.	AER	AER	AER
Agreement:			
	100%	100%	100%

TABLE 17

Coefficient of agreement for the cardiorespiratory factor.

Group	Sub-group I	Sub-group II
1. PWC	PWC	PWC
2. PWCW	PWCW	PWCW
3. VO2	VO2	VO2
4. VO2W	VO2W	VO2W
Agreement: 100%	100%	100%

the skinfold factor is explained by the high homogeneity of the two sub-groups for the seven variables loading under the factor. The lack of differentiation between the two sub-groups for the skating skill tests factor is of more concern. The results clearly indicate that in the two levels of organization of ice hockey (bantam and midget) no improvement was made by the players on their skating skills, as measured by the tests. This raises a question about the structure of the coaching and the teaching of the fundamentals of ice hockey skills, at least at the midget level. One should expect a difference between the two age categories on the skating skill tests factor.

4. Limitations of the skating skill tests.

In examining closely the different tests and in comparing the results of Macnab's study (1979), an explanation can be found to support the lack of differention on the skating skill tests factor for the two sub-groups studied. Macnab (1979) studied 15 young hockey players (from 8 to 12 years of age), for over a period of five years. The different comparisons are illustrated in figures 4, 5, 6, 7, 8, and 9 for the diffe-rent tests used in the making of the skating skill tests factor. Out of the six tests used; four showed a lack of discrimination between the age groups (forward speed skating, backward speed skating, agility without a puck and backward skating agility). The problem of discrimination is probably related to the short time of execution allowed to the players for the tests (approximatively 9 seconds for the agility tests, and 5 seconds for the speed tests). The other two tests (Marcotte and Hansen) showed a

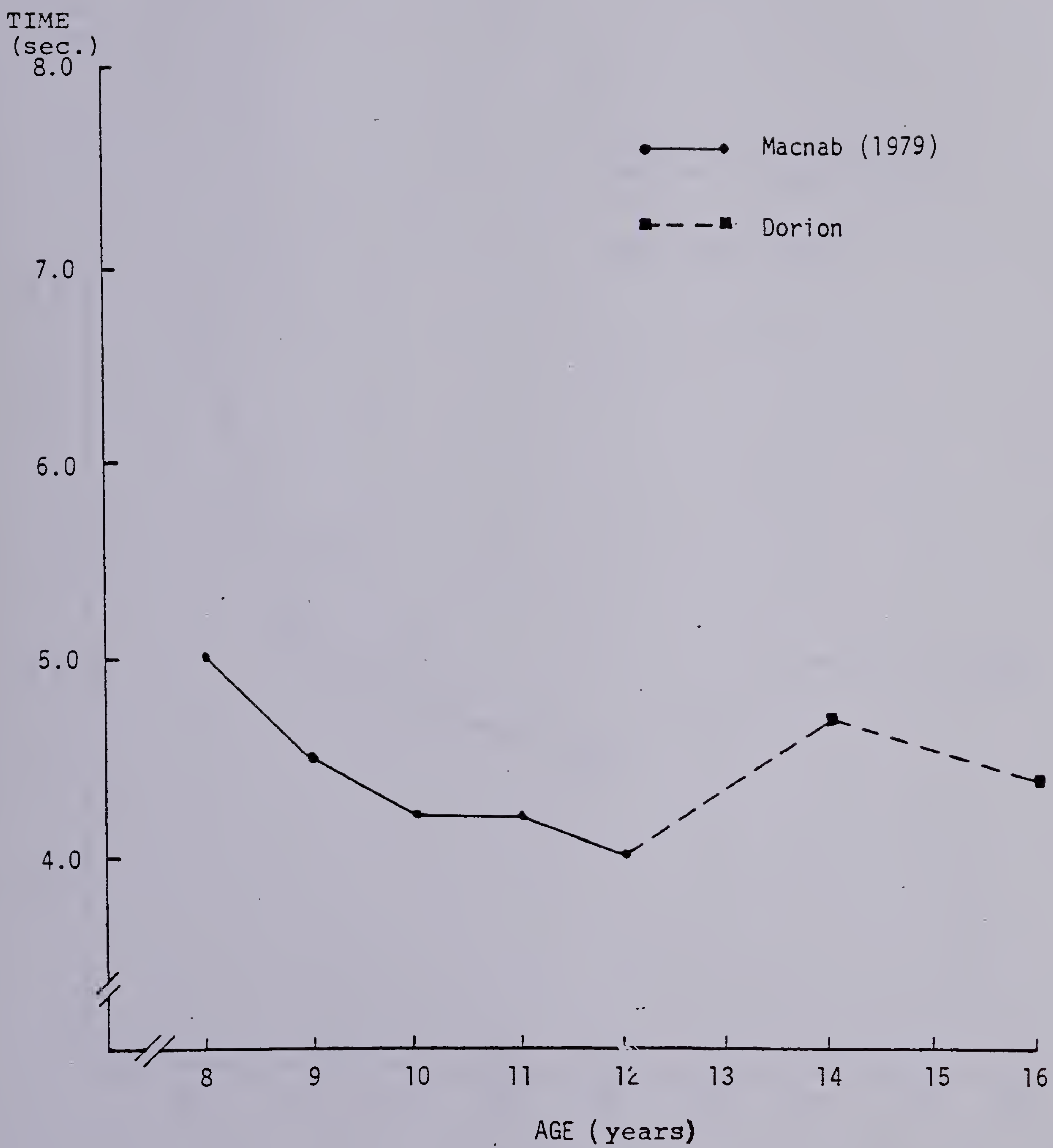

FIGURE 4 - Forward skating speed test - 90 feet.

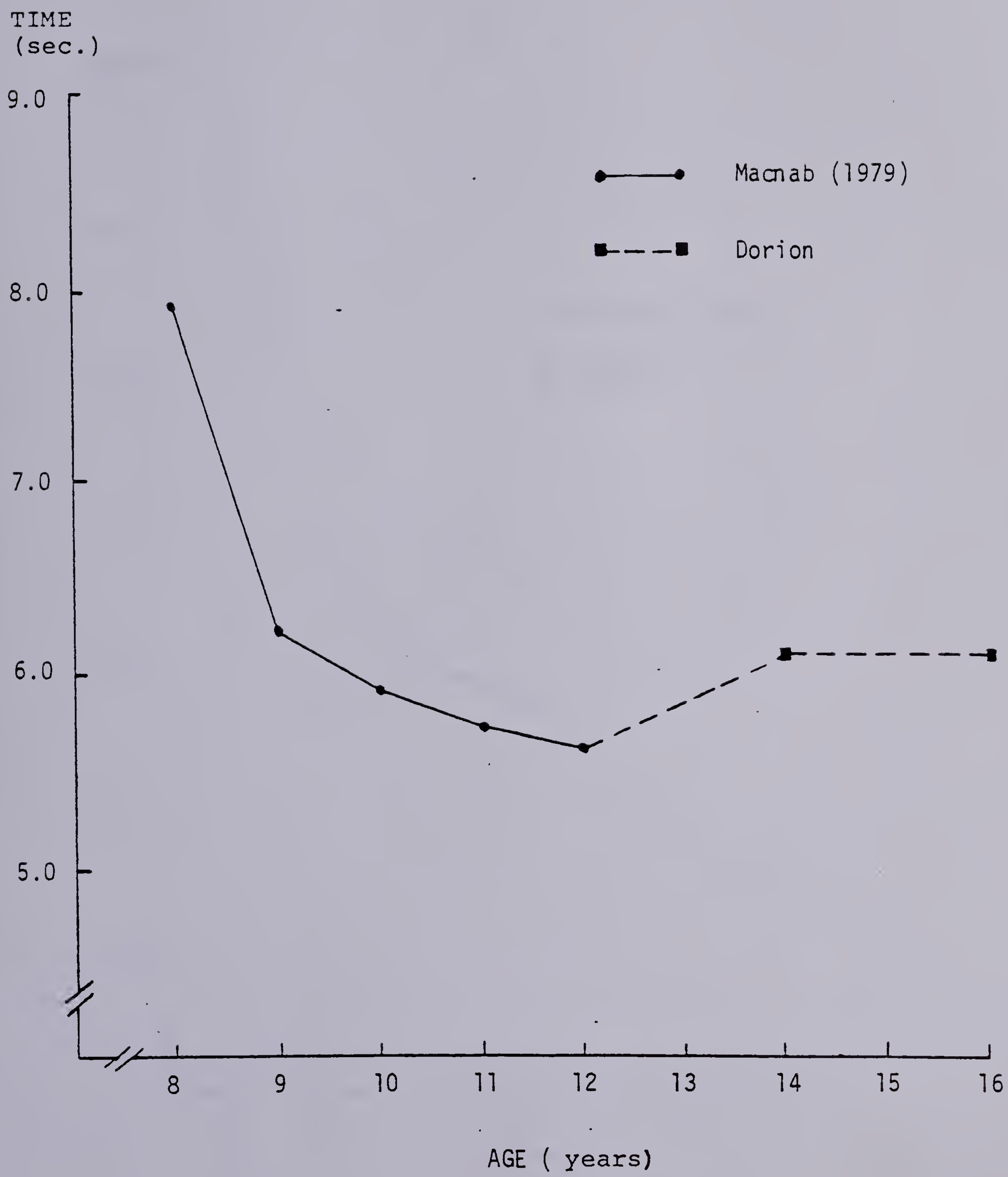

FIGURE 5 - Backward skating speed test - 90 feet.

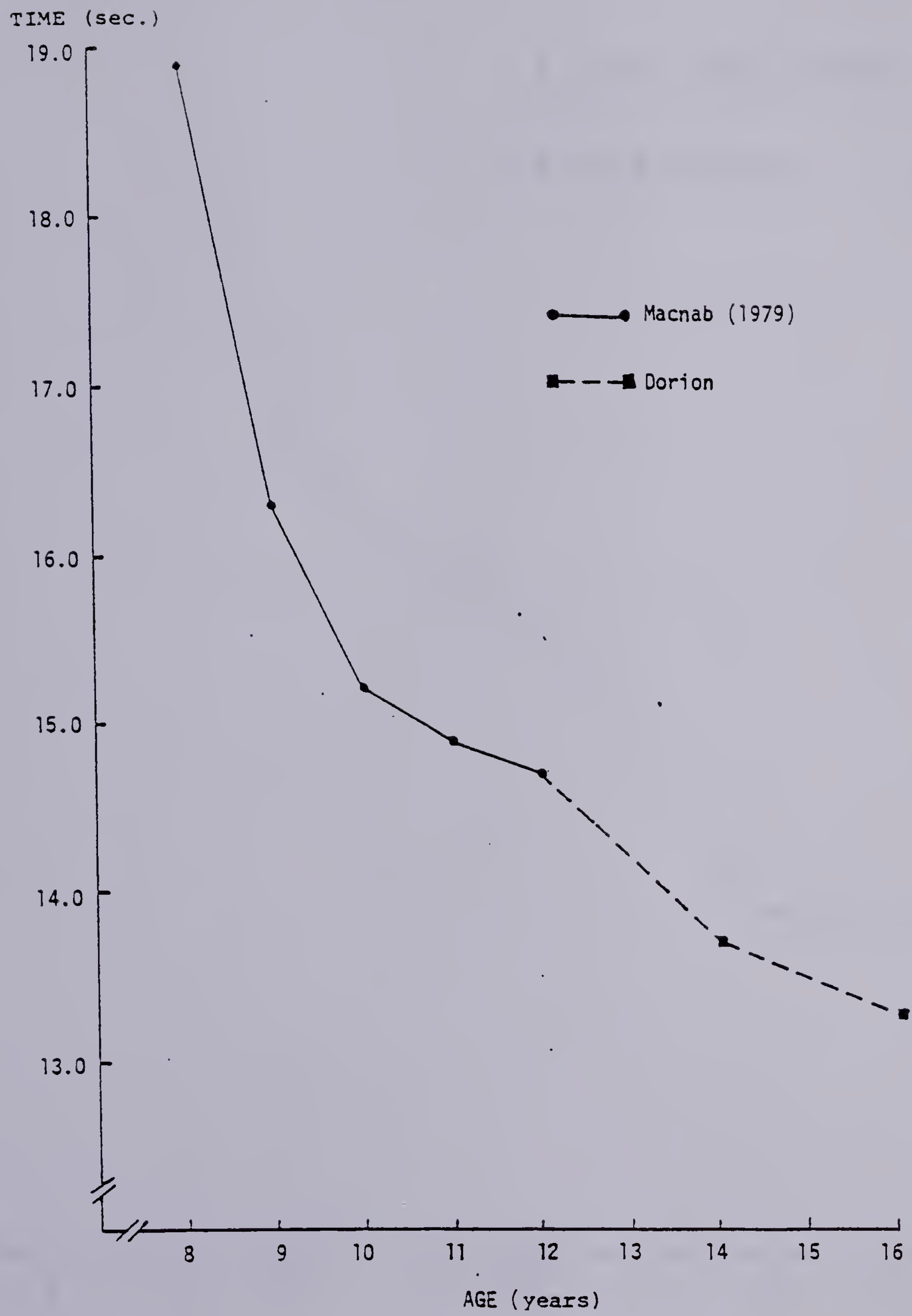

FIGURE 6 - Marcotte's agility test.

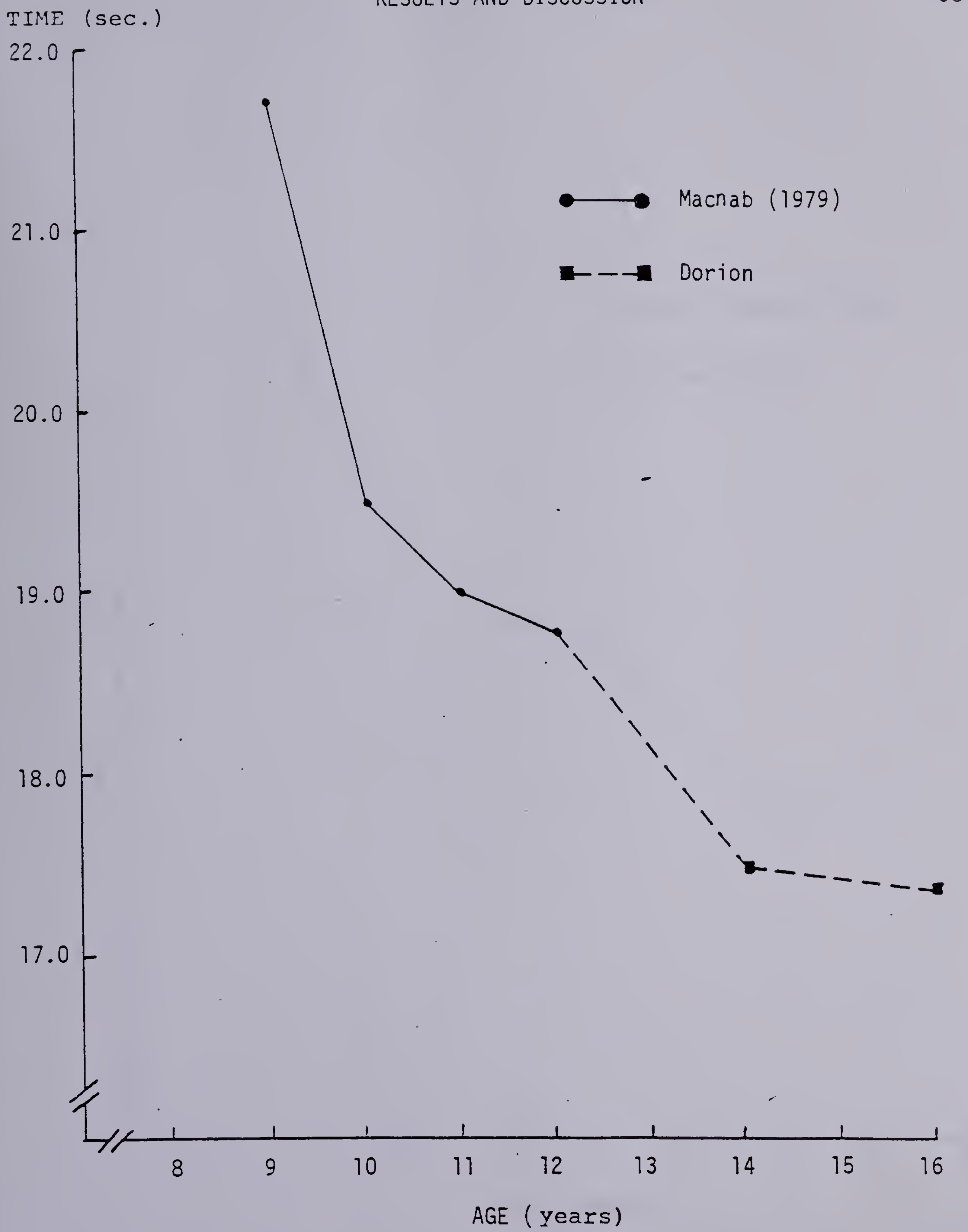

FIGURE 7 - Hansen's agility test.

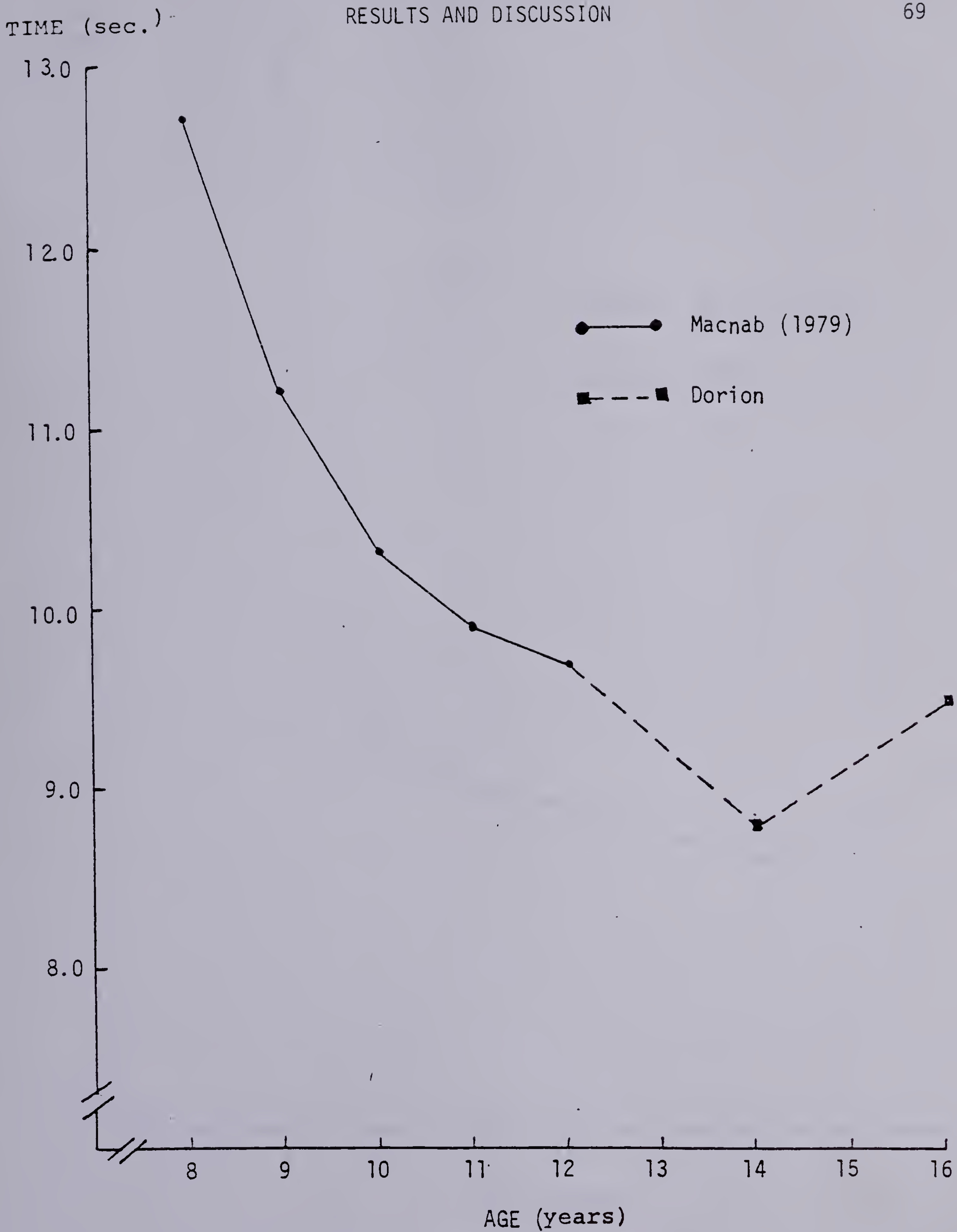

FIGURE 8 - Agility without a puck test.

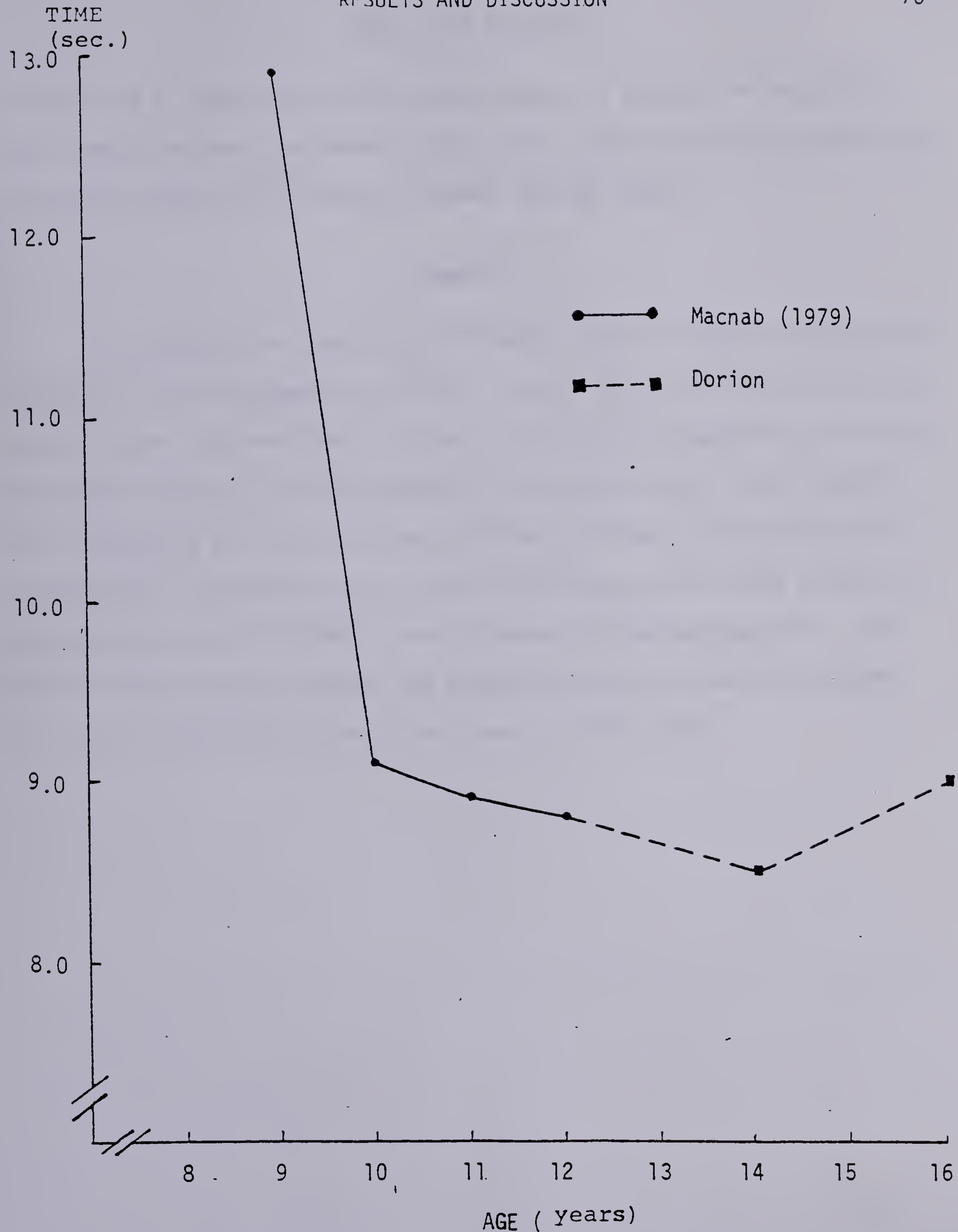

FIGURE 9 - Backward agility test.

longer time of execution for the tests (around 14 seconds for Marcotte's test, and 19 seconds for Hansen's test); this longer time of execution make possible a better discrimination between the age groups.

Summary.

As expected, a significant difference appeared between the two sub-groups for the anthropometrical factor. Such a difference may be explained by the growth and development process. No difference appeared for the skin-fold factor because of the homogeneity of the sub-groups on the measures. For the skating skill tests factor a difference between the sub-group was expected but did not occur. This lack of differentiation raises a question about the quality of the tests uses in measuring the skating skill. The lack of discrimination between the different age groups can be explained by a too limited time of execution allowed for the tests.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Summary

The chief purpose of this study was to analyze three of the components contributing to performance in ice hockey. Another purpose of the study was to analyze the structural validity of on-ice skill tests. Finally, the last purpose of the study was to compare two sub-groups of subjects (bantam and midget) on certains factors contributing to overall performance.

The players were analysed under three components:

1. skating skills,
2. physiological measures and predictions, and
3. anthropometrical measures.

The skating skill components were divided into three tests:

a) speed,
b) agility, and
c) endurance.

The physiological component was divided into three measures and predictions:

a) cardiorespiratory measures and predictions,
b) leg test, and
c) abdominal endurance.

The anthropometrical component was divided into seven measures:

a) age,
b) weight,

c) height,
d) widths of body segments,
e) lengths of body segments,
f) circumferences of body segments, and
g) skinfold measures.

In order to analyze the factors contributing to ice hockey performance, a factor analysis (principal components) was used and factor components were computed for the subjects.

The theoretical factors (three) were confirmed and, clarified. The anthropometrical factor (in theory) was subdivided into two factors: an anthropometrical factor and a skinfold factor. The skating skill tests were combined as one factor because as skating skill variables they all loaded together.

The structural validity of the tests used in measuring the skating skill was compared with other studies and the relationships between the tests and the skating skill tests factor were all similar to the ones reported in other studies.

In comparing the two sub-groups, a significant difference was found for the anthropometrical factor. No significant differences were found for the skinfold, the cardiorespiratory measures and predictions, and the skating skill tests factors.

B. Conclusion

The study found four factors involved in the performance aspect of ice hockey players. These factors confirmed the theoretical factors,

and clarified the anthropometrical factor. The discovery of the skating skill tests factor is a major step towards a better understanding of ice hockey players. The independence of the skating skill, as measured by the tests, from other components was demonstrated. Thus the specificity of ice hockey in terms of other physical activities has been confirmed.

The validity (structural) of the tests used for the skating skills has been shown to be accurate. The relationships establish in previous validity studies were in the same range as the ones reported in this study.

The lack of differentiation between the sub-groups on the skating skill tests factor raised questions about the quality of the teaching and the coaching of skating skills to ice hockey players.

C. Recommendations

This study was limited to the skating skill of the players. Other skills involved in ice hockey such as: shooting, passing, and body checking should be studied in the future. We also recommend the study of how "hockey instinct" can contribute of on-ice performances.

The physiological component was limited to cardiorespiratory measures and predictions, leg test, and abdominal endurance. Anaerobic power and endurance, the recovery rate, and the muscle fibers of ice hockey players should be included in further research studies.

New components such as the psychological profile of the player should also be taken into account in future studies.

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APPENDIX A

CORRELATION MATRIX*

AND FACTOR ANALYSIS

(for the 13 to 16 years old players)

*New abreviations for the matrices (appendix A, B, and C) can be found next page.

LIST OF ABREVIATIONS

FOR THE CORRELATION MATRICES

Thesis	Appendices
ABD	ABD
AER	AER
AGE	AGE
AOI	AGA
AWP	AGP
BA90	AR90
BA120	AR120
BIAC	BIAC
BITR	BITR
CAR	CBER
CFA	CAB
CHE	POI
CLE	CCU
CLL	CMO
CWR	COP
F90	A90
F120	A120
HAN	HAN
HEI	TAI
JAR	SSE
LAR	LBR
LFA	LAB
LLE	LCU
LLL	LJA
MAR	MAR
MID	MID
PBF	PDG
PWC	PWC
PWCW	PWCW
SIT	SIT
SUB	SUB
SUP	SUP
TRI	TRI
VO2	VO2
VO2W	VO2W
WEI	POID

CORRELATION MATRIX*

(13-16 year old boys)

	A90	AR90	A120	AR120	MAR	HAN	AGP	AGA	AER	AGE	PDID	TAI	LBR	LAB	LCU	LJA	CBER
A90	1.000	0.440	0.727	0.529	0.607	0.434	0.399	0.315	-.625	-.355	-.307	-.210	-.004	-.139	-.085	-.147	-.357
AR90		1.000	0.394	0.800	0.582	0.424	0.515	0.367	-.481	0.020	-.129	-.045	-.030	0.060	0.029	-.025	-.222
A120			1.000	0.645	0.614	0.546	0.336	0.334	-.477	-.472	-.337	-.308	-.117	-.171	-.061	-.150	-.336
AR120				1.000	0.657	0.557	0.543	0.455	-.527	-.174	-.208	-.169	-.052	-.035	-.005	-.087	-.236
MAR					1.000	0.680	0.607	0.461	-.533	-.207	-.195	-.230	-.067	-.124	-.095	-.191	-.189
HAN						1.000	0.616	0.560	-.320	-.056	-.132	-.096	0.024	-.053	-.206	0.010	-.107
AGP							1.000	0.591	-.476	0.192	-.023	0.075	0.094	0.110	-.039	0.087	-.068
AGA								1.000	-.245	0.142	0.036	0.063	0.094	0.006	-.089	0.009	0.010
AER									1.000	0.096	0.208	0.165	-.016	0.059	0.066	0.038	0.289
AGE		NS				NS		NS	NS	1.000	0.477	0.513	0.189	0.393	0.097	0.316	0.384
PDID		NS				NS	NS	NS			1.000	0.787	0.516	0.469	0.226	0.468	0.828
TAI		NS				NS	NS	NS				1.000	0.527	0.678	0.320	0.664	0.525
LBR	NS	NS	NS	NS	NS	NS	NS	NS	NS				1.000	0.184	0.186	0.283	0.375
LAB	NS	NS		NS	NS	NS	NS	NS	NS					1.000	0.369	0.541	0.268
LCU	NS	NS	NS	NS	NS		NS	NS	NS	NS					1.000	0.231	0.034
LJA		NS		NS		NS	NS	NS	NS							1.000	0.210
CBER						NS	NS	NS							NS		1.000
CAB						NS	NS	NS									
CPO		NS			NS	NS	NS	NS	NS								
CCU						NS	NS	NS							NS		
CMO		NS		NS	NS	NS	NS	NS							NS		
BIAC	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS							
BITR		NS		NS	NS	NS	NS	NS	NS								
TRI		NS					NS	NS	NS	NS		NS		NS	NS	NS	
SUB	NS	NS	NS	NS	NS	NS	NS	NS	NS						NS	NS	
MID	NS	NS	NS		NS		NS	NS	NS	NS				NS	NS	NS	
POI		NS	NS	NS	NS	NS	NS	NS	NS	NS				NS	NS	NS	
ABD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				NS	NS	NS	
PDG		NS					NS	NS	NS	NS		NS		NS	NS	NS	
SUP		NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS	NS	NS	
SIT	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS		NS	NS	NS
SSE		NS		NS		NS	NS	NS					NS				
PMC							NS										
PMCM						NS	NS		NS		NS	NS	NS	NS	NS	NS	NS
VO2							NS										
VO2M			NS	NS	NS	NS	NS		NS	NS		NS			NS	NS	NS

	CAB	CPO	CCU	CMO
A90	-.369	-.288	-.356	-.208
AR90	-.170	-.052	-.175	-.104
A120	-.330	-.282	-.328	-.313
AR120	-.239	-.146	-.223	-.129
MAR	-.177	-.080	-.207	-.027
HAN	-.103	-.064	-.146	-.041
AGP	-.052	0.395	-.045	0.044
AGA	-.047	0.134	0.033	0.014
AER	0.199	0.084	0.226	0.165
AGE	0.382	0.431	0.474	0.343
PDID	0.791	0.778	0.348	0.711
TAI	0.554	0.662	0.565	0.437
LBR	0.393	0.409	0.360	0.322
LAB	0.356	0.464	0.312	0.255
LCU	0.173	0.143	0.115	0.082
LJA	0.336	0.381	0.309	0.271
CBER	0.932	0.666	0.815	0.650
CAB	1.000	0.709	0.726	0.666
CPO		1.000	0.658	0.675
CCU			1.000	0.670
CMO				1.000
BIAC				
BITR				
TRI	NS	NS		
SUB				
MID				
POI				
ABD				
PDG				
SUP				
SIT	NS	NS		NS
SSE				
PMC				
PMCM	NS	NS	NS	NS
VO2				
VO2M	NS			

	BIAC	BITR	TRI	SUB	MID	POI	ABD	PDG	SUP	SIT	SSE	PMC	PMCM	VO2	VO2M
A90	-.045	-.238	0.153	-.063	0.094	0.103	0.089	0.159	0.156	-.028	-.297	-.367	-.256	-.369	-.169
AR90	-.118	-.137	0.046	0.044	0.114	0.018	0.099	0.087	0.034	0.049	-.073	-.216	-.187	-.262	-.191
A120	0.023	-.216	0.226	-.091	0.135	0.145	0.081	0.184	0.017	0.090	-.366	-.321	-.191	-.270	-.060
AR120	-.021	-.141	0.151	0.025	0.176	0.110	0.143	0.173	0.026	0.062	-.144	-.265	-.165	-.265	-.135
MAR	-.103	-.137	0.229	-.001	0.103	-.137	0.104	0.166	0.071	0.006	-.250	-.239	-.182	-.254	-.144
HAN	0.005	0.016	0.154	0.116	0.159	0.084	0.126	0.151	0.091	-.050	-.146	-.152	-.080	-.157	-.077
AGP	-.053	0.012	-.021	0.062	0.011	-.059	-.017	-.004	0.032	-.123	0.099	0.020	0.047	-.056	-.047
AGA	0.037	0.137	0.056	0.104	0.091	0.022	0.080	0.082	0.097	-.130	0.109	0.256	0.268	0.238	0.220
AER	0.107	0.137	-.106	-.075	0.016	-.052	-.019	-.054	-.124	0.020	0.192	0.214	0.117	0.253	0.111
AGE	-.049	0.388	-.126	0.193	0.049	-.114	0.032	-.040	0.127	-.113	0.494	0.404	0.271	0.356	0.050
PDID	0.298	0.608	0.168	0.558	0.509	0.387	0.463	0.412	0.320	-.127	0.384	0.461	-.027	0.394	-.248
TAI	0.247	0.546	-.079	0.270	0.244	0.159	0.209	0.135	0.137	-.123	0.374	0.479	0.107	0.411	-.102
LBR	0.240	0.340	0.152	0.262	0.204	0.223	0.249	0.252	0.206	0.004	0.084	0.185	-.059	0.148	0.168
LAB	0.207	0.336	-.004	0.170	0.095	0.108	0.091	0.090	0.068	-.185	0.307	0.200	-.014	0.145	-.162
LCU	0.217	0.204	-.012	0.019	-.005	0.035	-.011	0.017	-.089	0.081	0.149	0.230	0.136	0.218	0.092
LJA	0.158	0.432	-.116	0.107	0.048	0.032	0.073	0.006	0.102	-.172	0.212	0.319	0.111	0.283	-.029
CBER	0.233	0.508	0.240	0.613	0.555	0.403	0.494	0.467	0.297	-.104	0.400	0.428	0.037	0.396	-.122
CAB	0.264	0.468	0.108	0.492	0.374	0.399	0.353	0.297	0.213	0.017	0.389	0.430	0.056	0.393	-.113
CPO	0.230	0.482	0.057	0.395	0.296	0.239	0.259	0.227	0.156	-.118	0.367	0.365	-.011	0.303	-.205
CCU	0.158	0.574	0.174	0.534	0.400	0.361	0.458	0.393	0.370	-.148	0.362	0.454	0.050	0.413	-.136
CMO	0.208	0.387	0.157	0.424	0.402	0.315	0.398	0.334	0.269	-.018	0.303	0.267	-.076	0.233	-.223
BIAC	1.000	0.011	0.038	0.140	0.106	0.171	0.178	0.106	-.067	-.033	0.099	0.106	0.051	0.241	0.079
BITR	NS	1.000	0.174	0.460	0.335	0.318	0.324	0.332	0.315	-.009	0.280	0.408	0.156	0.243	-.074
TRI	NS		1.000	0.491	0.547	0.684	0.626	0.823	0.462	-.224	-.207	-.237	-.335	-.221	-.313
SUB				1.000	0.723	0.678	0.696	0.732	0.544	-.148	0.097	0.109	-.043	0.161	-.142
MID	NS				1.000	0.718	0.735	0.879	0.674	-.120	-.131	0.028	-.220	0.014	-.281
POI						1.000	0.742	0.897	0.607	-.156	-.185	-.065	-.262	-.048	-.255
ABD							1.000	0.800	0.631	-.198	-.094	0.017	-.222	0.024	-.249
PDG	NS							1.000	0.665	-.216	-.160	-.091	-.299	-.031	.325
SUP	NS								1.000	-.216	-.099	0.007	-.143	-.029	-.212
SIT	NS	NS			NS					1.000	-.017	-.084	-.012	-.046	0.039
SSE	NS			NS	NS		NS		NS	NS	1.000	0.258	0.089	0.206	-.051
PMC					NS	NS	NS	NS	NS	NS		1.000	0.860	0.967	0.706
PMCM	NS			NS						NS	NS		1.000	0.857	0.939
VO2					NS	NS	NS	NS	NS	NS				1.000	0.774
VO2M	NS	NS								NS	NS				1.000

*Upper half: correlation coefficient; lower half: N.S. = non-significant at α = 0.05.

Factor analysis

Variables	Factors I	II	III	IV	H^2
F90	-.309	.106	.664	-.171	.590
BA90	.002	-.017	.712	-.158	.532
F120	-.389	.130	.656	-.076	.604
BA120	-.131	.075	.811	-.112	.693
MAR	-.164	.113	.800	-.091	.688
HAN	-.049	.111	.718	-.005	.530
AWP	.200	-.088	.777	.050	.654
AOI	.131	.055	.638	.334	.538
AER	.137	-.017	-.619	.104	.413
AGE	.624	-.062	-.047	.193	.434
WEI	.856	.425	-.157	.012	.938
HEI	.848	.087	-.044	.069	.733
LFA	.440	.232	.039	-.029	.250
LAR	.599	-.004	.031	-.069	.365
LLU	.256	-.035	-.046	.090	.077
LLL	.566	-.032	.024	.071	.327
CAR	.650	.511	-.240	.101	.751
CFA	.710	.339	-.205	.072	.666
CWR	.787	.218	-.045	-.014	.670
CLE	.692	.447	-.208	.103	.733
CLL	.622	.350	-.111	-.043	.524
BIAC	.216	.122	-.040	.094	.072
BITR	.547	.329	-.067	.166	.439
JAR	.554	-.179	-.113	.024	.352
SIT	-.094	-.176	-.037	-.039	.043
TRI	-.120	.731	.095	-.190	.595
SUB	.305	.752	.026	.064	.663
MID	.177	.851	.089	-.068	.778
CHE	.040	.874	.045	-.103	.786
ABD	.145	.839	.066	-.059	.732
SUP	.090	.673	.067	-.043	.468
PBF	.041	.975	.096	-.127	.977
PWC	.471	.012	-.130	.856	.973
PWCW	.063	-.192	-.062	.959	.964
VO2	.372	.031	-.170	.882	.946
VO2W	-.199	-.198	-.075	.932	.966
Variance	25.4%	42.8%	52.8%	59.7%	

APPENDIX B

CORRELATION MATRIX

AND FACTOR ANALYSIS

(For the 13 and 14 year old players)

CORRELATION MATRIX*

(13-14 year old boys)

	A90	AR90	A120	AR120	MAR	HAN	AGP	AGA	AER	AGE	POIO	TAI	LBR	LAB	LCU	LJA	CBER	CAB	CPO	CCU	CMO	BIAC	BITR	TRI	SUB	MIO	POI	ABO	PDG	SUP	SIT	SSE	PWC	PWCW	VO2	VO2W
A90	1.000	0.188	0.216	0.049	0.269	0.331	0.430	0.057	-.206	-.314	-.373	-.332	-.144	-.305	-.115	-.291	-.367	0.375	-.320	-.306	-.303	-.138	-.167	0.007	-.104	-.139	-.042	-.115	-.050	-.214	-.173	-.174	-.210	0.010	-.225	0.041
AR90		1.000	-.110	0.693	0.460	-.141	0.137	0.002	-.262	-.101	-.240	-.150	0.049	-.108	0.241	-.210	-.271	-.269	-.229	-.205	-.171	-.198	-.163	0.099	-.121	0.001	-.036	-.097	0.042	-.002	0.077	-.170	-.147	-.034	-.158	0.010
A120			1.000	0.314	0.275	0.313	0.371	0.356	0.130	-.069	-.078	-.116	-.060	-.053	-.039	-.072	-.042	-.141	-.109	-.008	-.158	0.049	0.207	0.222	0.010	0.254	0.248	0.208	0.293	0.103	-.096	-.331	0.241	0.296	0.248	0.301
AR120	NS	NS		1.000	0.468	-.011	0.222	0.218	-.175	-.042	-.141	-.091	0.002	0.028	0.179	-.139	-.102	-.183	-.200	-.080	-.179	-.131	-.002	0.238	0.080	0.197	0.203	0.099	0.266	0.135	0.009	-.025	0.010	0.077	0.003	0.087
MAR					1.000	0.292	0.471	0.190	-.234	-.200	-.079	-.056	-.013	-.078	-.155	-.173	-.138	-.145	-.064	-.027	-.041	0.006	-.099	0.251	-.008	0.065	0.136	-.035	0.176	-.021	-.105	-.347	-.030	0.022	-.037	0.026
HAN		NS		NS		1.000	0.514	0.271	0.136	-.063	0.006	0.086	0.137	0.018	-.289	-.046	0.041	0.001	0.078	-.036	-.061	0.182	0.041	0.050	0.063	0.005	0.034	0.046	0.023	-.185	-.238	-.129	0.072	0.091	0.079	0.095
AGP		NS					1.000	0.056	-.142	-.091	-.017	0.011	0.108	0.089	-.025	-.079	-.023	-.055	-.074	-.009	-.117	0.013	-.036	0.233	0.109	0.072	0.050	0.063	0.137	-.028	-.293	-.185	0.018	0.045	0.007	0.036
AGA	NS	NS					NS	1.000	0.247	-.055	0.119	0.054	0.018	-.094	-.150	0.109	0.216	0.029	0.069	0.213	-.030	0.226	0.200	0.158	0.129	0.159	0.097	0.148	0.165	-.084	-.126	0.075	0.516	0.474	0.528	0.460
AER			NS	NS		NS	NS		1.000	0.114	0.166	0.166	-.045	-.011	-.223	0.184	0.239	0.207	0.153	0.226	0.231	0.152	0.087	-.064	0.104	0.136	0.055	0.173	0.037	0.074	0.073	0.198	0.309	0.231	0.308	0.207
AGE		NS	NS	NS		NS	NS	NS	NS	1.000	0.355	0.402	0.301	0.387	0.339	0.114	0.262	0.322	0.262	0.391	0.246	0.229	0.254	-.040	0.123	0.127	0.042	0.104	0.032	0.150	0.074	0.229	0.217	0.043	0.214	-.009
POIO			NS	NS	NS	NS	NS	NS	NS		1.000	0.841	0.627	0.671	0.185	0.631	0.874	0.858	0.829	0.845	0.838	0.431	0.515	0.332	0.743	0.640	0.592	0.583	0.568	0.573	-.039	0.225	0.355	-.118	0.348	-.230
TAI		NS	NS	NS	NS	NS	NS	NS	NS			1.000	0.696	0.745	0.258	0.756	0.641	0.674	0.705	0.614	0.629	0.354	0.555	0.129	0.493	0.427	0.404	0.385	0.336	0.367	-.046	0.226	0.389	-.001	0.372	-.119
LBR	NS	NS	NS	NS	NS	NS	NS	NS	NS				1.000	0.565	0.297	0.487	0.462	0.464	0.502	0.432	[illegible]	0.304	0.335	0.142	0.406	0.369	0.291	0.361	0.207	0.273	-.163	0.035	0.167	-.140	0.149	-.226
LAB		NS	NS	NS	NS	NS	NS	NS	NS					1.000	0.293	0.535	0.559	0.547	0.602	0.469	0.484	0.318	0.444	0.271	0.481	0.348	0.418	0.295	0.381	0.312	-.144	0.313	0.084	-.240	0.074	-.323
LCU	NS		NS	NS	NS		NS	NS			NS				1.000	0.273	0.083	0.209	0.046	0.099	0.104	0.032	0.345	0.067	0.038	0.075	0.129	0.071	0.110	0.138	0.187	0.195	0.100	0.008	0.105	-.005
LJA			NS	NS	NS	NS	NS	NS	NS	NS						1.000	0.492	0.551	0.520	0.395	0.044	0.229	0.479	0.018	0.313	0.215	0.302	0.272	0.182	0.219	0.014	0.203	0.408	0.116	0.400	0.029
CBER			NS	NS	NS	NS	NS								NS		1.000	0.876	0.761	0.831	0.775	0.379	0.444	0.405	0.765	0.633	0.563	0.620	0.590	0.528	-.112	0.249	0.403	-.005	0.411	[illegible]
CAB			NS	NS	NS	NS	NS	NS										1.000	0.781	0.763	0.830	0.380	0.445	0.296	0.642	0.526	0.522	0.530	0.485	0.528	0.002	0.228	0.356	-.053	0.365	.138
CPO			NS		NS	NS	NS	NS	NS						NS				1.000	0.709	0.811	0.268	0.452	0.220	0.579	0.479	0.492	0.436	0.412	0.443	-.064	0.519	0.184	-.205	0.185	.300
CCU			NS	NS	NS	NS	NS								NS					1.000	0.780	0.339	0.370	0.301	0.654	0.578	0.486	0.515	0.505	0.524	-.093	0.212	0.439	0.040	0.450	-.044
CMO		NS	NS	NS	NS	NS	NS	NS							NS						1.000	0.336	0.364	0.298	0.660	0.551	0.554	0.515	0.511	0.556	0.034	0.205	0.223	-.178	0.230	.262
BIAC	NS		NS	NS	NS	NS	NS		NS						NS							1.000	0.171	0.207	0.434	0.319	0.342	0.368	0.315	0.253	-.070	0.184	0.264	0.073	0.287	0.046
BITR	NS	NS		NS	NS	NS	NS		NS													NS	1.000	0.169	0.350	0.261	0.367	0.393	0.296	0.175	0.022	0.255	0.312	0.007	0.301	0.011
TRI	NS	NS				NS		NS	NS	NS		NS	NS		NS	NS							NS	1.000	0.626	0.579	0.709	0.668	0.845	0.594	-.307	-.057	-.009	-.162	-.001	-.179
SUB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS					NS										1.000	0.044	0.759	0.795	0.828	0.706	-.219	0.175	0.170	-.167	0.169	-.244
MIO	NS	NS			NS	NS	NS	NS	NS	NS					NS											1.000	0.771	0.705	0.889	0.804	-.094	-.066	0.199	-.082	0.194	-.150
POI	NS	NS			NS	NS	NS	NS	NS	NS					NS												1.000	0.728	0.915	0.726	-.139	0.048	0.012	-.250	0.020	-.299
ABO	NS	NS		NS	NS	NS	NS	NS	NS	NS					NS													1.000	0.811	0.807	-.148	0.044	0.234	-.016	0.226	-.082
PDG	NS	NS			NS	NS	NS	NS	NS	NS					NS	NS													1.000	0.788	-.221	-.029	0.074	-.178	0.078	-.225
SUP		NS	NS	NS	NS	NS	NS	NS	NS	NS					NS								NS							1.000	-.018	-.035	0.166	-.084	0.156	-.150
SIT	NS	NS	NS	NS	NS			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			NS	NS	NS		NS	1.000	0.039	-.043	0.003	-.027	0.025
SSE	NS	NS		NS		NS	NS	NS					NS						NS			NS		NS	NS	NS	NS	NS	NS	NS	NS	1.000	0.007	-.120	0.037	-.121
PWC		NS		NS	NS	NS	NS						NS	NS	NS				NS					NS	NS		NS		NS	NS	NS	NS	1.000	0.079	0.991	0.305
PWCW	NS	NS		NS	NS	NS	NS			NS	NS	NS	NS			NS	NS	NS		NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS		1.000	0.872	0.980
VO2		NS		NS	NS	NS	NS						NS	NS	NS				NS					NS	NS	NS	NS		NS	NS	NS	NS			1.000	0.820
VO2W	NS	NS		NS	NS	NS	NS			NS		NS			NS	NS	NS	NS		NS		NS	NS	NS		NS		NS		NS	NS	NS				1.000

*Upper half: correlation coefficient; lower half: N.S. = non-significant at $\alpha = 0.05$.

Factor analysis

Variables	I	II	III	IV	h^2
		Factors			
F90	-.171	-.30	.867	-.199	.825
BA90	-.217	.039	.644	-.189	.499
F120	-.188	.153	.862	.149	.808
BA120	-.150	.200	.783	-.016	.669
MAR	-.078	.073	.928	-.117	.886
HAN	.028	.072	.678	.173	.506
AWP	-.012	-.056	.891	-.006	.800
AOI	-.018	.121	.594	.377	.509
AER	.071	.009	-.787	.243	.682
AGE	.405	.072	-.155	-.004	.197
WEI	.893	.380	-.102	-.014	.959
HEI	.901	.060	-.023	.046	.829
LFA	.659	.101	.169	-.073	.558
LAR	.749	.104	-.044	-.118	.576
LLU	.287	-.014	-.110	.097	.152
LLL	.647	-.059	-.058	.277	.516
CAR	.656	.547	-.184	.109	.774
CFA	.754	.382	-.121	.015	.739
CWR	.797	.288	-.007	-.108	.733
CLE	.668	.439	-.159	.159	.695
CLL	.647	.454	-.202	-.095	.697
BIAC	.364	.178	.048	.180	.217
BITR	.538	.238	-.172	.264	.451
JAR	.248	-.053	-.175	-.078	.102
SIT	.013	-.194	-.098	-.097	.112
TRI	-.029	.821	.168	-.091	.724
SUB	.428	.801	-.001	-.026	.830
MID	.288	.830	.068	.033	.778
CHE	.289	.819	.058	-.091	.771
ABD	.183	.844	.036	.010	.774
SUP	.193	.781	.066	-.025	.650
PBF	.169	.966	.115	-.050	.981
PWC	.340	.049	-.041	.919	.961
PWCW	-.076	-.110	-.011	.975	.964
VO2	.281	.078	-.087	.947	.971
VO2W	-.239	-.120	-.032	.946	.955
Variance	28.6%	46.5%	58.1%	65.4%	

APPENDIX C

CORRELATION MATRIX

AND FACTOR ANALYSIS

(For the 15 and 16 year old players)

CORRELATION MATRIX*

(15-16 year old boys)

	A90	AR90	A120	AR120	MAR	HAN	AGP	AGA	AER	AGE	POID	TAI	LBR	LAB	LCU	LJA	CBER	CAB	CPO	CCU	CMO	BIAC	BITR	TRI	SUB	MID	POI	ABO	PDG	SUP	SIT	SSE	PWC	PWCW	VO2	VO2W
A90	1.000	0.340	0.572	0.362	0.357	0.353	0.327	0.430	-.490	-.023	-.133	0.089	0.054	0.122	0.031	0.125	-.375	-.375	-.253	-.195	-.136	-.240	0.142	0.095	0.071	0.268	0.338	0.227	0.273	0.373	-.067	-.240	-.205	-.128	-.229	-.110
AR90		1.000	0.478	0.829	0.490	0.567	0.546	0.444	-.375	0.030	-.069	0.081	-.055	0.294	0.060	0.206	-.212	-.144	-.064	-.140	-.021	-.128	-.123	-.091	0.148	0.197	0.046	0.185	0.082	-.001	0.058	-.014	-.332	-.313	-.328	-.278
A120			1.000	0.532	0.440	0.576	0.346	0.297	-.330	-.202	-.247	-.148	-.134	0.044	-.133	0.022	-.272	-.324	-.242	-.215	-.190	-.277	-.063	0.083	-.052	0.129	0.029	0.044	0.095	0.012	0.149	-.134	-.420	-.304	-.407	-.259
AR120				1.000	0.523	0.658	0.619	0.473	-.410	-.020	-.166	-.086	-.078	0.100	0.007	0.092	-.251	-.279	-.087	-.220	-.033	-.171	0.071	-.054	0.029	0.173	-.018	0.130	0.059	-.054	0.095	-.101	-.399	-.314	-.389	-.282
MAR					1.000	0.680	0.610	0.548	-.305	-.130	-.170	-.259	-.146	-.060	-.022	-.133	-.146	-.217	-.060	0.137	0.137	-.286	0.080	0.200	0.049	0.138	0.137	0.157	0.165	0.091	-.008	-.247	-.231	-.168	-.258	-.150
HAN						1.000	0.666	0.603	-.245	-.129	-.251	-.240	-.008	-.065	-.158	-.008	-.191	-.194	-.223	-.269	-.023	-.144	0.049	0.168	0.111	0.203	0.103	0.182	0.186	0.093	0.071	-.176	-.465	-.308	-.429	-.283
AGP							1.000	0.668	-.279	-.079	-.271	-.157	-.052	0.105	0.116	0.016	-.237	-.239	-.021	-.298	0.025	-.058	-.107	-.029	0.006	-.007	-.021	-.051	-.007	-.026	-.033	0.012	-.313	-.148	-.293	-.124
AGA								1.000	-.180	-.074	-.133	0.007	0.080	0.038	0.224	-.018	-.273	-.251	-.043	-.295	0.025	-.010	0.043	-.014	0.037	0.031	0.007	0.041	0.021	0.140	-.066	-.021	-.065	0.026	-.057	0.045
AER								NS	1.080	0.092	0.365	0.310	0.100	0.050	0.066	-.110	0.416	0.339	0.186	0.304	0.168	0.258	-.048	-.054	-.184	0.013	-.002	-.030	-.039	-.142	-.020	0.284	0.232	-.015	0.247	-.037
AGE	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.000	0.170	0.279	0.066	0.227	0.118	0.243	0.008	-.016	0.159	0.041	0.123	0.262	-.026	0.061	-.064	-.115	-.110	-.029	-.093	-.092	-.313	0.136	0.165	0.076	0.162	0.073
POID	NS	NS		NS	NS			NS		NS	1.000	0.634	0.404	0.047	0.219	0.247	0.783	0.666	0.625	0.834	0.599	0.495	0.476	0.219	0.397	0.487	0.402	0.548	0.428	0.225	-.115	0.288	0.330	-.273	0.348	-.308
TAI	NS	NS	NS	NS			NS	NS				1.000	0.331	0.499	0.476	0.540	0.314	0.280	0.419	0.376	0.309	0.490	0.205	-.095	-.006	0.136	0.820	0.206	0.072	-.035	-.083	0.308	0.342	-.065	0.369	-.081
LBR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			1.000	-.239	0.150	0.123	0.329	0.299	0.243	0.255	0.294	0.262	0.376	0.209	0.169	0.253	0.249	0.219	0.276	0.169	0.202	0.078	0.143	-.063	0.132	-.092
LAB	NS		NS	NS	NS	NS	NS	NS	NS		NS			1.000	0.325	0.523	-.169	-.027	0.125	-.063	-.049	0.187	-.093	-.080	-.144	-.103	-.098	-.007	-.088	-.078	-.206	0.108	-.014	-.053	0.028	-.038
LCU	NS	NS	NS	NS	NS	NS	NS		NS	NS			NS		1.000	0.221	0.093	0.126	0.298	0.089	0.074	0.257	0.108	-.094	-.011	-.120	-.079	-.071	-.097	-.225	-.005	0.226	0.326	0.176	0.295	0.116
LJA	NS	NS	NS	NS	NS	NS	NS	NS	NS				NS			1.000	-.104	0.832	0.153	0.090	0.102	0.208	0.218	-.025	-.062	-.049	-.076	0.047	0.022	0.041	-.081	0.053	-.057	-.215	-.034	-.234
CBER		NS			NS	NS				NS				NS	NS	NS	1.080	0.749	0.503	0.718	0.478	0.432	0.326	0.240	0.469	0.559	0.418	0.491	0.475	0.160	0.091	0.256	0.253	-.196	0.251	-.222
CAB		NS				NS				NS				NS	NS	NS		1.000	0.538	0.613	0.474	0.140	0.205	0.077	0.334	0.281	0.217	0.306	0.212	0.826	0.126	0.287	0.326	-.061	0.338	-.086
CPO		NS		NS	NS		NS	NS	NS	NS				NS		NS			1.000	0.476	0.513	0.463	0.183	0.024	0.176	0.146	0.102	0.176	0.112	-.067	-.131	0.323	0.304	-.088	0.299	-.124
CCU	NS	NS			NS					NS				NS	NS	NS				1.000	0.539	0.298	0.471	0.270	0.396	0.473	0.440	0.561	0.437	0.308	-.102	0.165	0.190	-.306	0.197	-.351
CMO	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				NS	NS	NS					1.000	0.355	0.195	0.160	0.209	0.313	0.208	0.368	0.260	0.130	-.019	0.205	0.154	-.191	0.141	-.229
BIAC		NS		NS		NS	NS	NS						NS	NS							1.000	0.083	0.211	0.004	-.024	-.060	0.107	-.109	-.207	-.003	0.386	0.417	0.177	0.434	0.035
BITR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				NS	NS				NS		NS	NS	1.000	0.363	0.442	0.428	0.407	0.373	0.473	0.396	-.018	-.043	0.810	-.254	-.018	-.299
TRI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS	NS	NS		NS	NS		NS			1.080	0.471	0.531	0.639	0.531	0.796	0.446	-.176	-.232	-.372	-.473	-.364	-.460
SUB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS			NS			NS			1.000	0.641	0.694	0.682	0.784	0.472	-.031	-.125	0.072	-.083	0.066	-.083
MID		NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS	NS	NS			NS			NS				1.000	0.712	0.735	0.882	0.647	-.111	-.146	-.173	-.445	-.172	-.438
POI		NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS	NS	NS			NS			NS					1.000	0.785	0.890	0.641	-.227	-.318	-.040	-.279	-.057	-.273
ABO		NS	NS	NS	NS	NS	NS	NS	NS	NS				NS	NS	NS			NS			NS						1.000	0.790	0.581	-.222	-.215	-.077	-.413	-.069	-.393
PDG		NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS	NS	NS			NS			NS							1.000	0.660	-.213	-.254	-.238	-.171	-.244	-.463
SUP		NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS		NS	NS	NS	NS		NS									1.000	-.277	-.255	-.192	-.304	-.212	-.313
SIT	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS					1.000	0.026	0.101	0.200	0.109	0.179
SSE		NS	NS	NS		NS	NS	NS		NS			NS	NS		NS				NS			NS		NS	NS					NS	1.000	0.082	-.054	0.097	-.093
PWC	NS							NS		NS			NS	NS		NS				NS	NS		NS		NS	NS	NS	NS		NS	NS	NS	1.000	0.791	0.979	0.771
PWCW	NS				NS		NS	NS	NS	NS		NS	NS	NS				NS	NS		NS	NS			NS						NS	NS		1.000	0.763	0.984
VO2								NS		NS			NS	NS		NS					NS		NS		NS	NS	NS	NS			NS	NS			1.000	0.755
VO2W	NS				NS		NS	NS	NS	NS		NS	NS	NS	NS			NS	NS			NS			NS						NS	NS				1.000

*Upper diagonal: correlation coefficient; lower diagonal: N.S. = non-significant at $\alpha = 0.05$.

Factor analysis

Variables	Factors I	II	III	IV	H^2
F90	.187	.587	-.169	-.008	.409
BA90	.015	.771	.193	-.194	.669
F120	-.033	.584	-.181	-.246	.435
BA120	-.035	.800	.059	-.216	.691
MAR	.120	.676	-.137	-.046	.492
HAN	.086	.751	-.131	-.204	.631
AWP	-.095	.747	.050	-.070	.574
AOI	.006	.718	.064	.155	.544
AER	.001	-.470	.304	-.022	.314
AGE	-.081	-.053	.295	.051	.099
WEI	.621	-.271	.701	-.020	.952
HEI	.143	-.048	.755	.071	.597
LFA	.340	-.056	.257	.069	.190
LAR	-.171	.165	.370	-.074	.199
LLU	-.057	.101	.464	.232	.283
LLL	-.039	.119	.422	-.170	.223
CAR	.618	-.379	.415	.002	.698
CFA	.383	-.370	.480	.069	.526
CWR	.238	-.136	.640	.051	.488
CLE	.621	-.359	.431	-.110	.712
CLL	.383	-.068	.460	-.031	.364
BIAC	.027	-.182	.642	.192	.483
BITR	.534	.049	.154	-.073	.316
JAR	-.190	-.172	.505	-.090	.329
SIT	-.138	.014	-.031	.138	.039
TRI	.628	.005	-.218	-.319	.544
SUB	.760	.072	-.049	.128	.601
MID	.844	.120	-.001	-.185	.761
CHE	.886	.076	-.152	-.003	.815
ABD	.843	.116	.080	-.115	.734
SUP	.653	.081	-.233	-.130	.504
PBF	.930	.091	-.133	-.213	.937
PWC	.033	-.294	.324	.885	.975
PWCW	-.314	-.141	-.121	.920	.979
VO2	.018	-.290	.346	.852	.930
VO2W	-.320	-.104	-.156	.921	.865
Variance	20.7%	39.8%	48.5%	55.7%	

APPENDIX D

LETTER OF CONSENT

CONSENTEMENT EN CONNAISSANCE DE CAUSE AUX EPREUVES D'EFFORT

A. Explication des épreuves d'effort.

En premier lieu, votre enfant va effectuer une épreuve d'effort progressif sur bicyclette ergométrique. Les charges initiales de travail seront faibles et il pourra facilement accomplir l'exercice; elles seront augmentées par la suite en fonction de sa capacité au travail. Nous pouvons arrêter l'épreuve dans le cas où il y aura des manifestations de signes de fatigue ou votre enfant pourra y mettre fin lui-même s'il ressent de la fatigue ou s'il ne se sent pas à l'aise. Nous ne voulons pas qu'il fournisse des efforts trop intenses qu'il aurait mal à supporter.

En deuxième lieu, votre enfant aura à accomplir un test à effort maximal de trente (30) secondes.

B. Risques et effort difficile à supporter.

Il est possible que des incidents surviennent au cours de l'épreuve. Parmi ces incidents citons: une tension artérielle devenant anormale, un évanouissement, un rythme cardiaque désordonné, très rarement une attaque cardiaque. Toutes les précautions seront prises pour que ces risques soient réduits au minimum et, en particulier, des examens préliminaires seront passés et des observations seront faites durant l'épreuve. Une équipe d'urgence bien formée, disposant de matériel adapté est prête à in-

tervenir dans le cas où il se produirait quelque chose d'anormal.

C. Avantages.

Les résultats obtenus à l'épreuve d'effort peuvent faciliter un diagnostic ou la détermination de la nature des activités dans lesquelles l'enfant peut s'engager sans risque, pratiquement.

En plus, les résultats obtenus seront utilisés dans le cadre d'un projet de recherche d'évaluation des joueurs de hockey.

D. Questions.

Nous serons heureux de répondre aux questions touchant les procédures utilisées durant l'épreuve d'effort ou lors de l'estimation de la capacité fonctionnelle que vous pourriez vous poser. N'hésitez pas à demander des explications supplémentaires si vous avez le moindre doute.

E. Consentement en toute liberté.

Vous êtes entièrement libre de nous autoriser à faire subir l'épreuve d'effort progressif ou, au contraire, de refuser de faire passer cette épreuve à votre enfant. En plus, vous pouvez retirer votre enfant de l'épreuve en tout temps.

J'ai pris connaissance de cette formule, j'en comprends les procédures de l'épreuve que mon enfant va subir et je consens à ce qu'il participe à l'épreuve.

Date

Signature du père ou de la mère

APPENDIX E

DATA COLLECTION FORMS

(on-ice variables)

COLLECTE DES DONNEES

POUR LE GROUPE: ______________________

date: ________________

test #1 vitesse

#id.	90a -	120a	90r -	120r
1. ____	____	____	____	____
2. ____	____	____	____	____
3. ____	____	____	____	____
4. ____	____	____	____	____
5. ____	____	____	____	____
6. ____	____	____	____	____
7. ____	____	____	____	____
8. ____	____	____	____	____
9. ____	____	____	____	____
10. ____	____	____	____	____

test #2-3 agilite: Hansen et Marcotte

#id	hansen	marcotte
1. ____	____	____
2. ____	____	____
3. ____	____	____
4. ____	____	____
5. ____	____	____
6. ____	____	____
7. ____	____	____
8. ____	____	____
9. ____	____	____
10. ____	____	____

test #4-5 agilité arrière et sans-rondelle

#id.	arrière	sans-rond.
1. ____	____	____
2. ____	____	____
3. ____	____	____
4. ____	____	____
5. ____	____	____
6. ____	____	____
7. ____	____	____
8. ____	____	____
9. ____	____	____
10. ____	____	____

test #6 puissance aérobique

#id.	# tours
1. ____	____
2. ____	____
3. ____	____
4. ____	____
5. ____	____
6. ____	____
7. ____	____
8. ____	____
9. ____	____
10. ____	____

APPENDIX F

DATA COLLECTION FORMS

(Laboratory variables)

PROCEDURES EN LABORATOIRE

I) Inscription:

nom:____________________ date de naissance:__________________

position:______________ côté dominant: D. G.

équipe:______________ poids:________kg. taille:________cm.

II) Mesure anthropométrique:

	1ere mes.	2eme mes.	moy.
A) longueur segmentaire:			
1) bras	________	________	________mm.
2) avant-bras	________	________	________mm.
3) cuisse	________	________	________mm.
4) jambe	________	________	________mm.
B) circonférence segmentaire:			
1) bras	________	________	________mm.
2) avant-bras	________	________	________mm.
3) poignet	________	________	________mm.
4) cuisse	________	________	________mm.
5) mollet	________	________	________mm.
C) largeur segmentaire:			
1) bi-accromial	________	________	________mm.
2) bi-trochentère	________	________	________mm.
D) pli cutané:			
1) triceps	________	________	________mm.
2) sub-scapulaire	________	________	________mm.
3) mid-axila	________	________	________mm.
4) poitrine	________	________	________mm.
5) abdomen	________	________	________mm.
6) supra-iliac	________	________	________mm.
% de graisse			________%

IV) Puissance aérobique:

de la bicyclette: ________

PWC_{170}:

	1^{ere}étape	2^{eme}étape	3^{eme}étape
A) tension	________kp.	________kp.	________kp.
B) cycle de pédalage			
1^{ere} min.	________rev.	________rev.	________rev.
2^{eme} min.	________	________	________
3^{eme} min.	________	________	________
4^{eme} min.	________	________	________
moyenne	________	________	________
C) fréquence cardiaque			
1^{ere} min.	________	________	________
2^{eme} min.	________	________	________
3^{eme} min.	________	________	________
4^{eme} min.	________	________	________
moyenne	________	________	________

D) récupération

1^{ere} min. ________ 2^{eme} min. ________

PWC_{170}: __________ VO_2 max. : __________

PWC_{170}/kg.: __________ VO_2/ kg. : __________

---

remarques : ____

____

____

____

date de la prise des données: ______________________